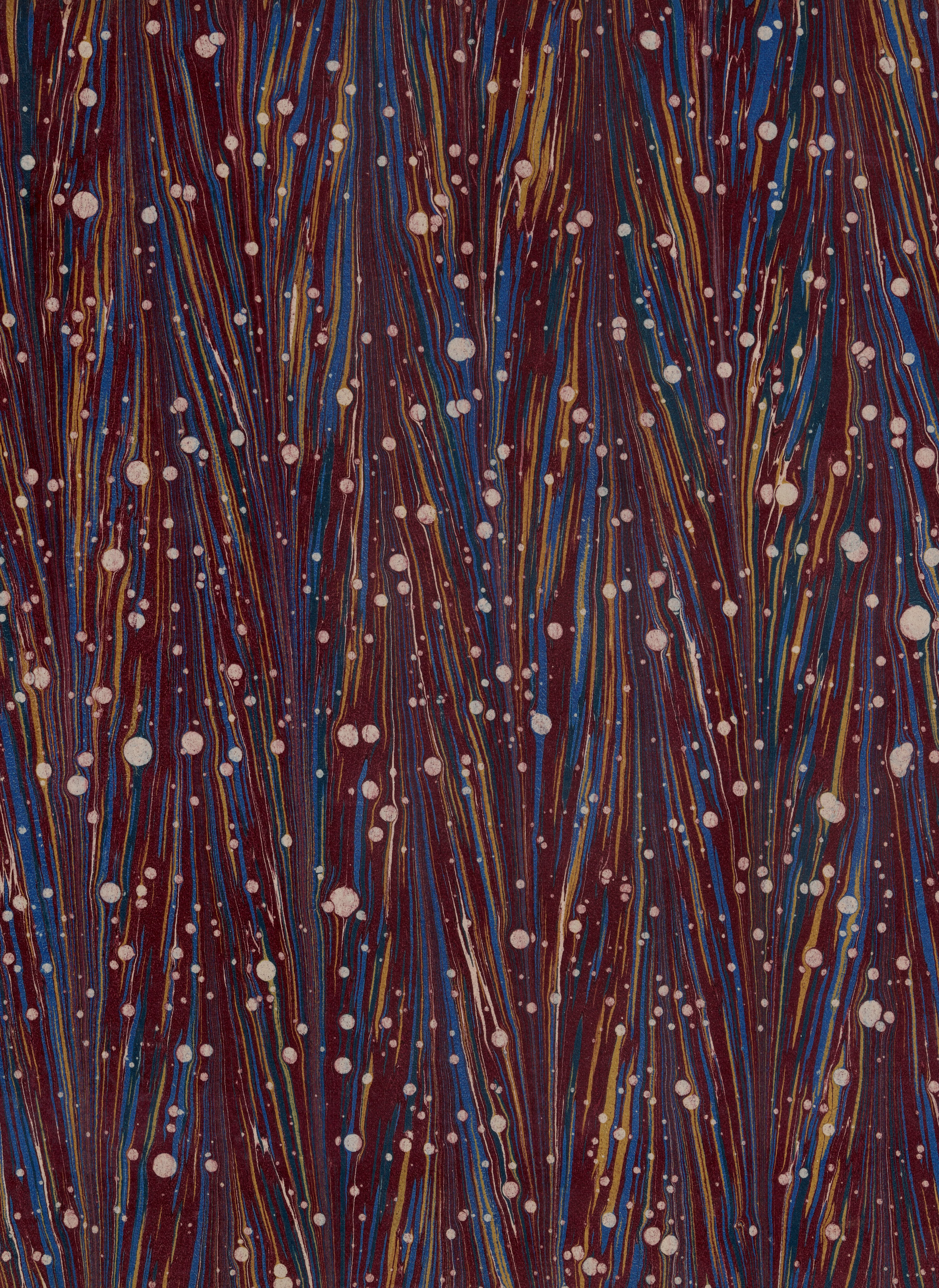

The Air We Breathe.

BY · E · A · LETTS ·

Doctor of Philosophy. Doctor of Science.
Fellow of the Royal Society of Edinburgh.
Fellow of the Chemical Societies of London and Germany.
Fellow of the Royal University of Ireland.
Professor of Chemistry in Queen's College, Belfast.

A POPULAR ACCOUNT OF AIR,
ITS COMPOSITION, FUNCTIONS AND IMPURITIES.

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At the two great crises of our life air is the all-potent factor. Our first breath ushers us into the world, and with our last we quit it. We can for a time exist without food, without drink, without a dwelling, and without clothes, but deprive us for a few minutes - a very few - of air, and we die.

And yet as Angus Smith says, "when we are children, air is to us nothing. A vessel of air is a vessel with nothing in it. Early nations thought in the same way. It was a great day for the world when air was found to be something material and to be capable of weighing down the scales of a balance."

For now we go to the other extreme and have learnt to recognise the enormous importance of air and its variety of functions in nature.

We live <u>in</u> air and to a certain extent on air for it is continually flowing into our blood, and is indeed one of our most important food stuffs.

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Within our bodies it is the source of warmth and muscular movement. Outside our bodies it serves us in a hundred ways. Its force propels our ships and drives our windmills. It is from atmospheric moisture that we derive our water supplies and ultimately our water power. Air feeds our furnaces and may be said to provide us with steam power also. So important is its condition as to warmth, speed, and weight, that we provide observatories all over the world to measure its frequent variations in these respects. Its condition as to purity influences our health in a marked degree. Substances present in air nourish plants and without it they could not exist. And even in those vast geological changes which the surface of the earth has experienced, air has played an important part. Thus the whole subject of air is of the utmost importance from a great many aspects. In this essay the following points will be specially considered:-

(1) The composition of air.

(2) Its impurities - their significance, effects and removal.

(3) Its functions.

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To the best of my belief the ancient Greek philosophers were the first to speculate in anything like a rational way on the nature of air, and the conclusion at which they arrived was that it was an element,or one of the first principles of matter. Empedocles considered that all things were composed of four elements, Earth, Air, Fire, and Water, and the idea still lingers with us, as in ordinary language we often speak of these as "elements". Anaximenes went further and maintained that air is the "arche" or first principle from which all other things are produced. The belief that air is an element was retained until the seventeenth century when Hookeand Mayhow (and in a lesser degree Rey) came to the conclusion that it contains a certain principle which supports combustion, that is to say, which causes or allows combustible things to burn in it - a principle which Mayhow called by several names such as:- "Nitre air," Fire air," and the "Nitro Aerial Spirit,"- which occurs also in a more condensed form in ordinary nitre or saltpetre. None of these observers isolated this principle. It

was reserved for Priestley to do so. On the first of August 1774 Priestley isolated oxygen for the first time+ and proved it to be a constituent of air. He obtained the gas by heating red oxide of mercury.- a substance which may be produced by heating mercury at a lower temperature in contact with air. He almost immediately detected the remarkable property which this gas has of supporting combustion better, and animal life longer than the same volume of air.

Two years earlier i.e., in 1772 Dr Rutherford Professor of chemistry in the University of Edinburgh had examined air as follows:- He first allowed animals to breathe in it, then he treated the air which remained with caustic potash. What was left although still like air was found to have totally different properties, for it now extinguished a candle and animals died when immersed in it. In the same year Priestley found that if charcoal is burnt in a closed volume of air as long as possible, and the air thus treated is allowed to stand over quicklime, it diminishes by one fifth and with the residue he made the same observation as Rutherford, viz:-that

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+Quite independantly, and at about the same time the Swedish Chemist Scheele obtained oxygen.

it would neither support life nor combustion.

Priestley, however, did not apparently consider that his experiments proved that air contained two distinct gases. We owe the first definite statement to this effect to Scheele who ascertained it from his own exhaustive and admirable experiments. One of these alone is capable of supporting combustion, while the other is neither capable of maintaining combustion nor of being breathed for any length of time by itself.

An experiment of Lavoisier's also demonstrated in a simple and conclusive manner that air contains two distinct gases. By heating mercury in a measured volume of air he found that about one fifth is absorbed by the metal, forming the compound (red oxide of mercury or "red precipitate") - from which Priestley had obtained oxygen, while the remaining four fifths had all the properties of the "mephitic" air of Rutherford. Lavoisier correctly maintained that this gas is an undecomposable substance or element as we now say, and he called it "azote" from its antagonism to animal life. This constituent

Chaptal suggested should be called nitrogen (i.e., saltpetre producer) - the name we now know it by.

The net result of all these different researches was, then, the proof that air is composed of two different gases which are called oxygen and nitrogen respectively.†

Oxygen may be separated from the air by several different processes, some of which are carried out on a commercial scale as the gas is largely employed along with hydrogen or coal gas for producing the "lime light" - and also for obtaining a very high temperature (Appendix B). It is the active ingredient in the air and its properties are of a very striking kind. Thus substances like charcoal, sulphur and phosphorus burn in it with extraordinary brilliancy and so do all the ordinary combustibles. Even iron and steel, if once heated sufficiently combine with the gas when plunged into a jar of it burning brightly and throwing off showers of sparks. The separation of nitrogen from air is effected with far greater ease than that of oxygen. The simplest plan is to burn some phosphorus in a jar of air, when

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† Quite recently another constituent has been discovered. See Appendix "A".

after the combustion is over the residual gas consists entirely of nitrogen. Or if air is passed through a tube containing copper heated to redness, the same result is obtained.

The properties of nitrogen are of no striking interest. It is the inert constituent of the atmosphere. The only positive characteristics it has, capable of ready demonstration, are that it extinguishes flame and that an animal if immersed in it quickly dies.

Now comes the question - In what condition are the oxygen and nitrogen in the air ? Is air a chemical compound, or merely a mechanical mixture ? The distinction between the two is very important and is always well marked.

In an elaborate and careful series of experiments,Cavendish showed in 1783 that the composition of the air, that is to say, the relative proportions of its two constituents does not vary from time to time nor in different localities - so far at least as he could ascertain - and this induced many chemists, notably Prout, Döbereiner, and Thomson to

conclude that air is a compound; for constancy in chemical composition is one of the characteristics of compounds. But against this view Dalton protested, and without going further into the controversy, it may be stated at once that he was correct. Air is not a compound at all, but simply a mixture of oxygen and nitrogen.

The distinction between mixtures and compounds is a question of considerable importance in chemistry, and speaking generally, the differences between the two are sharp and well defined.

1. In the first place if two substances are merely mixed, no heat is generated; whereas almost always when a compound is formed, heat is given out. Now if oxygen and nitrogen are mixed together in the proportions in which they are present in air, no heat is given out, but a mixture is obtained having all the properties of air.

2. Secondly the properties of a compound are never the same as those of its constituents. Now the properties of air are not different, or not very different from the properties of the two gases

contained in it. They are just the properties which one would anticipate from a mere mixture of the two - a kind of mean in fact between those of the very active substance oxygen and the inert gas nitrogen. Or to put it in another way - the properties of the air are those of oxygen, the nitrogen merely diluting it. Take for instance the case of a candle burning in oxygen and burning in air. In both we have combustion, but while in the first it is intense, in the second it is slow.

3. In the third place, the composition of a compound is invariable and cannot be altered; thus water always contains exactly * -

Hydrogen	11.136
Oxygen	88.864
	100.000

and so long as we are dealing with pure water these

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* Recent research has thrown some doubt upon the exactness of these figures, without however contradicting the cardinal principle of constancy in the composition of compounds.

proportions express its compositions in 100 parts- no matter how the water may have originated.

But the composition of the atmosphere is <u>not</u> invariable, although Cavendish believed that it was so. More accurate methods of analysis have shown that he was mistaken, though the error he fell into was very pardonable considering the primitive methods and apparatus he was compelled to use.

Much more accurate methods of research have since been employed and a vast amount of time and patience have been expended on the subject. The following table shows the results obtained by some of the most reliable workers, the numbers being the percentage of oxygen in air by volume.

	<u>Maximum</u>	<u>Minimum</u>
Bunsen about 1846	20.970	20.840
Regnault (Paris)	20.999	20.913
Angus Smith (various localities)	20.950	20.857
Hempuel 1886	21.000	20.860

The maximum observed was therefore 21.000 of oxygen and the minimum 20.840, and the largest variation

Q.160 which though small is without doubt due to natural causes and not to experimental errors.

Moreover we can easily change the composition of air without materially altering its properties, by certain mechanical processes which would not change the composition of a compound. So putting all these arguments together we clearly prove that air is a mechanical mixture and not a compound.

The next point I come to is how the proportions of nitrogen and oxygen present in air are actually ascertained both by weight and by volume. Now as pure air contains only the two things, oxygen and nitrogen it is sufficient to determine the amount of one of them to get at the composition of the air, for the amount of the other will obviously be the difference between the total quantity of pure air taken and the quantity of the one constituent determined. The constituent actually determined is always oxygen which may be removed from air by a variety of processes.

A rough method consists in burning phosphorus in a jar of air standing over water. The phosphorus combines with the oxygen and the resulting compound is dissolved by the water. After the

combustion is over and the remaining nitrogen has cooled down, it is found to occupy about four fifths of the original volume, so that roughly speaking air is composed of one fifth oxygen and four fifths nitrogen. But this method is not sufficiently delicate for scientific purposes.

For more exact determinations of the oxygen by volume an apparatus called the "Eudiometer" is employed, which in its primitive form was devised by Priestley and named by him Eudiometer or measurer of fine-ness, as he believed that the fine-ness of the air or its purity depended upon the proportion of oxygen it contained. Essentially this instrument consists of an accurately graduated tube standing over mercury and so arranged that a volume of air can be measured with great exactness under given conditions of temperature and pressure. As gases expand or contract under different conditions of temperature and pressure, it is necessary when comparing their volumes to take these factors into consideration. But as the laws governing their behaviour in this respect are simple it is easy to cal-

calculate what the volume of a gas will be at any given temperature and pressure from an observation of its volume at another temperature and pressure. It has been decided among scientific men to compare all gases at the temperature of freezing water (i.e. on the Fahrenheit scale 32° or 0° on the Centigrade) and at the mean atmospheric pressure (equivalent to the pressure of a column of mercury thirty inches, or seven hundred and sixty millemetres, high.)These conditions of temperature and pressure are spoken of as "normal" . The substances employed in the eudiometer for absorbing the oxygen are (1) a mixture of pyrogallic acid and potash (2) phosphorus (3) heated metallic copper. Another method consists in mixing the measured volume of air with a measured volume of hydrogen - rather more than is required to combine with the oxygen, and then exploding the mixture by an electric spark (which is made to pass between two wires sealed into the eudiometer). The contraction occurring after the explosion is then measured, and as two volumes of hydrogen and one volume of oxygen form water which condenses, one

third of the contraction corresponds with the volume of oxygen contained in the air.

As to the weight of oxygen contained in air it may either be calculated from the volume or determined directly by passing a known weight of air over red hot copper contained in a glass tube. The copper then absorbs the oxygen and combines with it, while the nitrogen passes on unchanged. If the tube containing the copper is weighed before and after the experiment, the increase corresponds with the oxygen. The following is a summary of the mean results obtained by the best workers in this field.

			Percentage of oxygen by weight.
Dumas and Boussingault	-	Paris 1841 . . .	.23.005
Löwy	-	Copenhagen . . . . . 1841 . . .	.22.998
Stas	-	Brussels . . . . . 1842 . . .	.23.100
Marignac	-	Geneva . . . . . 1842 . . .	.22.990

To sum up: air contains about twenty three per cent by weight of oxygen and seventy seven per cent

of nitrogen, while the proportions by volume of the two are about twenty one and twenty nine respectively. But as the result of an immense number of determinations of the composition of the air by different workers there can be no doubt that it varies to a certain extent. The variation it is true, is only slight amounting as we have seen to not more than 0.160 per cent of oxygen by volume. Locality has a distinct influence in this respect. Thus Angus Smith found that air at the sea side and from Scbtch moors may contain as much as 21 (20.999) volumes per cent of oxygen, while in houses it may sink to 20.82, and in theatres, crowded places and mines it may fall as far as 20.26. There is also some evidence to show that the air of the tropics contains slightly less oxygen than that of northern latitudes.

We now come to the consideration of the impurities of air - a question of great hygienic importance as fresh air is absolutely necessary for health.

IMPURITIES OF AIR.

NAME.	CHIEF SOURCES.	Amount in Grams per Cubic Metre of Air.		OBSERVER AND DATE.
		Maximum.	Minimum.	
Water ...	Evaporation from seas, lakes, and land. Combustion and respiration ..	5·470	0·44	Herbertson, at Ben Nevis 1892-93.
Carbonic Acid ...	Putrefaction, decay, fermentation, combustion and respiration ...	0·630		A. Smith, Pit of Standard Theatre, London, 1864.
Sulphuric Acid ... (Anhydrous)	Oxidation of Sulphuretted Hydrogen evolved from putrefying matter, combustion of coals, volcanos ...		0·055	Müntz and Aubin, S. and Central America, 1882.
		·0074		A. Smith, Underground Railway, London, 1869.
			0·0003	A. Smith, Blackpool, 1869.
Nitric Acid / Nitrous Acid	Oxidation of Ammonia—electric discharges through air ...	...	...	
Common Salt ...	Sea Spray—combustion of coals ...	0·0009		A. Smith, Underground Railway, London, 1869.
Dust { Inorganic Particles	Pulverized minerals, soil, &c.		0·00006	A. Smith, Inellan, Firth of Clyde, 1869 (?)
Dust { Organic Particles	Debris of p'ants and animals, and spores of lower organisms	0·006	0·023	Tissandier, Paris.
Ammonia ...	Putrefaction and decay—volcanos, evaporation of water (?)	0·0028	0·0009	Truchot, Auvergne.
		0·0007(1)	0 0001(2)	A. Smith. (1) Air from Midden, 1869. (2) Air from Firth of Clyde
Ozone ...	Electrical discharges through air	0·0025	0	
Perox. of Hydrogen		...	...	

Perfectly pure air is never met with in nature, and a similar remark applies to water. The causes of air pollution are nūmerous, and some are not far to seek, for air is more or less in a constant state od agigation, blown hither and thither over sea and land and constantly taking up foreign matters in its course. From the sea it takes up water vapour and even salt, while from the land it derives solid particles of dust and various gases.

I have prepared a table showing the chief impurities in air, with their sourses and amount (maximum and minimum), from the most trustworthy authorities. In addition to these, air occasionally contains others, such as sulphuretted hydrogen, carbonic oxide, sulphorous anhydride, Hydrocarbons, &c.

According to Dewar an average sample of air has the following composition.

	Vols. per 1000
Nitrogen	779.0600
Oxygen	206.5940
Aqueous vapour	14.0000
Carbonic acid	0.3360
Ammonia	0.0080
Ozone	0.0015
Nitric acid	0.0005

Some of these impurities are of great importance and deserve special consideration.

Water. This impurity, if impurity we consider it - is the chief foreign substance in air and plays a very important part in the economy of nature. Deposited from the atmosphere by cold, it assumes the form of rain, snow or hail and thus gives origin to streams, rivers and lakes. In this way it provides animals and plants with the moisture they require for their vital processes, while it is also the ultimate source of our water power.

The actual weight of water contained in air is often large as the following consideration will show. Suppose we have a cubic mile of air which by passing over the sea becomes saturated with water, say at a temperature of thirty five degrees Centigrade (ninety five Fahrenheit.) Suppose further that this air reaches land where a frost exists and that it is cooled to freezing point - what would happen ? It would deposit no less than 140,000 tons of rain, sleet, hail or snow as

the case might be !

Atmospheric moisture is unfortunately a very prominent impurity of the air of the British Isles. We have too much of it for our comfort, but as we shall see presently it has compensating advantages. For the moment let us consider how it is determined. The most accurate method consists in passing a known volume of air through a weighed tube containing some substance like chloride of calcium or sulphuric acid which has a strong attraction for moisture. The increase in the weight of the tube after the experiment gives us its amount. Then there is a very beautiful little instrument called "Daniel's Dew point hygrometer" which enables us to ascertain directly the "dew point" or temperature at which the air is <u>saturated</u> with water. It consists of two bulbs containing ether (See Plate 3) which communicate with each other by a tube bent twice at right angles. One of the bulbs is made of black glass and has a thermometer within it, while the other is of ordinary glass and is enveloped in muslin. To make an observation; ether

is poured over the muslin and evaporates rapidly producing cold and this causes the ether within the apparatus to distil over from the blackened bulb, with the result that the temperature of the latter falls. The moment when the dew point is reached is known by a ring of dew forming outside the blackened bulb. The temperature of the latter is now read, and the actual quantity of moisture in the air ascertained from specially constructed tables*

For most purposes it is sufficient to ascertain the relative humidity of the air by the difference in temperature of the wet bulb and dry bulb thermometer. The wet bulb thermometer as

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* The actual weight of water capable of being taken up by one cubic meter or air at different temperatures is as follows:-

Co	Grams Water	Co	Grams Water.
- 10	2·284	25	22·843
0	4·871	30	30·095
5	6·795	35	39·252
10	9·362	40	50·700
15	12·746	100	588·730
20	17·157		

its name implies is a thermometer whose bulb is kept constantly moistened with water which rises by capillary attraction up a piece of lamp cotton dipping in a vessel of water below, while above it is connected with a piece of muslin surrounding the thermometer bulb. The dryer the air so much the faster does the water evaporate from the muslin, and as a consequence, the temperature falls in proportion (as evaporation produces cold): thus with very dry air the wet bulb thermometer marks a much lower temperature than the dry bulb (or ordinary) thermometer does. Therefore the difference in the readings of the two is roughly speaking proportional to the dryness, but inversely proportional to the moisture. Special tables were prepared years ago by Glaisher, and others have since been introduced for enabling an observer to properly interpret the readings of the double instrument.

Carbonic Acid. Carbonic acid or to speak more correctly, carbonic anhydride is one of the chief impurities in air and plays a very important role in the lives of plants and animals, and not

only so, but also in inorganic nature it exercises a very decided influence in inducing those geological changes whereby the configuration of the earth's surface has been, and still is becoming altered.

The sources of this gas are numerous both in nature and artificially. It is produced whenever an ordinary combustible burns, whether a candle, lamp, wood, coal, charcoal or coke. It is formed during putrefaction and decay, and it is exhaled with every breath which an animal takes. Now, carbonic acid when inhaled in anything like a large quantity, kills animals as surely and nearly as swiftly as a cannon ball, and even when taken into the lungs in small amount, it is decidedly poisonous.

Consider now the extent to which the different processes are going on around us which I have pointed out as sources of the gas, all contributing their quota to render the air more and more unfit for respiration. At first sight the prospect appears an alarming one for human beings, for it is natural to imagine that the quantity of carbonic

acid must be increasing and will bye and bye destroy all animal life on the globe.

Fortunately however there is a beautiful device of nature's for checking the increase of carbonic acid in the air. Plants come to our aid; for it is one of their functions (as Priestley first ascertained experimentally) to renovate air charged with the gas. Under the influence of light the green colouring matter (chlorophyll) which they contain decomposes the carbonic acid of the air and although the actual chemical processes occurring are probably complicated, the final result is simple and consists in the complete decomposition of the carbonic acid, the carbon which it contains being absorbed as food by the plant, while the oxygen, its other constituent, is discharged into the air. Thus plants undo the work which animals have performed and the two exercise a reciprocal action on the air resulting in their mutual benefit. The animal breathes in oxygen and exhales carbonic acid. The plant absorbs this poisonous matter, feeds upon it indeed, and exhales

pure oxygen, so that nature by this beautiful device constantly keeps the carbonic acid below an injurious amount - just sufficient for vegetables to feed on, and just insufficient to harm animals. Indeed the limit seems to be a narrow one for often in very foggy weather the quantity of carbonic acid in the air is probably on the verge of being injurious to human life.

For various reasons the amount of carbonic acid in air affords the readiest criterion of its purity, and therefore it is essential that the chemist should have an accurate and simple means of measuring its amount. Such a method is Pettenkofer's which in a slightly modified form is now generally employed. Its principle is as follows. A definite amount of any acid requires a definite amount of an alkali or base to neutralize it, and neutralization is indicated by the change in colour which certain colouring matters experience. To determine carbonic acid in air a very weak solution of an alkali is made, one measure of which will exactly neutralize a certain quantity of carbonic

acid. A dry bottle is then filled with the air to be examined and a volume of the alkaline solution is then placed in it which is more than sufficient to combine with the carbonic acid. The bottle is next stoppered, well shaken and its contents allowed to remain at rest for some time when the carbonic acid is gradually absorbed. The colouring matter is then added, and the excess of the alkali ascertained by running in a solution of acid of known strength until neutrality is indicated by the change in colour.*

* In practice a solution of baryta is used of such a strength that 1 cubic centimetre will neutralize 1/10 cubic centimetre of carbonic acid. A solution of hydrocloric acid is also made so that 1 cubic centimetre of it will just neutralize 1 cubic centimetre of the baryta. Suppose a bottle containing 3 litres (three thousand cubic centimetres) of air is taken and 20 cubic centimetres of baryta are added. After standing &c., a drop of a solution of phenolphthaleine is added which gives an intense red colour with the excess of baryta. The hydrochloric acid is then added cautiously until the red colour just vanishes. Suppose eight cubic centimetres were necessary. Then 20-8 = 12 cubic centimetres of baryta have been neutralized by carbonic acid whose amount in three litres of air is therefore 1·2 cubic centimetres or 10,000 volumes of the air contained four volumes of carbonic acid.

Much work has been done regarding the actual quantity of carbonic acid present in air. The following is a summary of the results obtained.

	Volumes of Carbonic acid In 10,000 volumes Air
Pure air (Country & sea side)	3
Air in well ventilated houses, below . .	7
Air during fogs	7-10
Air in theatres, close places &c. . . .	20 & above
Air in mines (average of A.Smith's results)	78·5

According to Angus Smith we instinctively avoid an atmosphere containing ten volumes. The amount of carbonic acid in the country during the night is greater than during the day varying to the extent of about 1/5 volume in 10,000 of air or about five per cent of its total amount. That this is caused partly by plants no longer decomposing the gas (as they require sunlight for the purpose) and partly by their actually exhaling it is almost certain. Thus the amount of carbonic acid in air at sea does not vary more than by 1/50 of a volume in 10,000 of air. (See Appendix E)

We now come to the other impurities which it is true occur only in minute amount in air, but which are nevertheless of much importance, as their quantity exercises a considerable influence on the healthiness of the atmosphere, and they are also of importance in Agriculture.

I have before pointed out that air is constantly taking up impurities from land and sea. From the land gaseous emanations, vapours and solid matters in the form of dust: from the sea chiefly water vapour, but also spray and as a consequence salt. Now when such air is cooled down, a great deal of the water is precipitated as rain, and the rain carries down a very considerable proportion of the atmospheric impurities.

Thus rain may be viewed as a device of nature's for purifying air, and it follows that the study of the substances found in rain should give us important imformation regarding the impurities of air, for it presents some of them to us in a more concentrated condition than they occur in air itself and renders their determination possible.

This subject has been very carefully investigated by a number of eminent observers - Boussingault, Pierre, Barral and others on the Continent and by the late Dr. Angus Smith in the British Isles. The actual quantities of the impurities washed out of air by rain, appear minute when expressed in percentages, or even indeed in parts per million of rain water examined, but viewed from another standpoint, namely in relation to the annual rainfall, their amount is seen to be really very considerable. Barral found that every acre of land at Paris receives annually by rain

	lbs.
Nitric Acid	56·0
Ammonia	13·4
Chlorine	11·4
Lime	27·4
Magnesia	8·0
	116·2

(Contained probably in about 13,000,000 lbs of rain.)

Thus from the agriculturalists' point of view rain is a most important substance, not only

moistening the land and nourishing the crops, but also being of great manurial value, and we can understand in the light of these facts how it is possible to produce crops without manure by the system of fallow land.

Turning our attention to some of the chief impurities of rain.

Ammonia. During the decay and putrefaction of organic substances, and especially of animal matter, ammonia is produced and partly at least makes its way into the air. The amount of ammonia found in rain is in all probability a fair measure of the amount of organic impurity in the atmosphere (Angus Smith). But there are other sources of atmospheric ammonia. Thus by sending an electrical discharge through a damp atmosphere, nitrate of ammonia is formed (Berthelot) and this process must occur in every thunderstorm. It is also stated that the same salt is produced by the direct union of nitrogen and water when the latter is evaporated in air, and lastly ammonia is thrown into the air from volcanos.

Albumenoid Ammonia. (Organic Matter.)

The organic matter in air we may consider as its sewage, for by it we understand the debris of plants and animals and some of their products of decomposition, as well as the spores of certain minute organisms. Its amount is usually inferred from that of what is called "albumenoid ammonia;" that is to say the ammonia which is produced when albumenoid substances are boiled with a mixture of permanganate of potash and caustic potash. In this way the chemist imitates in the laboratory the very process which nature performs is disposing of the debris of plant, and (especially of) animal life. The amount of albumenoid ammonia obtained from rain thus indicates the quantity of vegetable and animal matter existing in it undecomposed.

Nitric Acid. This substance is produced in nature by the oxidation of ammonia and organic matter. Its amount is therefore not only a measure of the impure matter in air, but also of the progress made in purifying it (Angus Smith). It must

however be observed that atmospheric electricity also causes the formation of nitric acid directly from the air by the union of nitrogen, oxygen and water.

Sulphuric Acid. Like nitric acid this substance results in nature from the oxidation of organic matter. The most dangerous products of decomposition come from substances containing nitrogen and sulphur. The first we find in ammonia and nitric acid, the second in sulphuric acid. (Angus Smith.)

But there is a second important source of this acid, in coal smoke, for coal always contains sulphur and the latter when burnt escapes into the air as sulphurous acid gas which is eventually further oxidized to sulphuric acid. Thus the amount of sulphuric acid in rain not only indicates pollution from organic sources, but pollution caused by the smoke arising from dwellings and factories.

Chlorides. That salt (chloride of sodium) is carried from the sea by air in the form of spray

far inland, is proved by the fact that it is found on windows far from the sea during gales. Angus Smith was anxious to know how far this might be considered the natural mode of supplying the substance to soils. His experiments show that it is found in greatest quantity in the rain collected at the coast; but that there is another source of it, namely the coal burnt in our towns. "The rule is that it diminishes as we leave the coast and increases again as we enter towns: but it does not rise so high in towns as it does during wind from the sea and near the coast. Taking London and the South it is the distance from the Western sea chiefly, that governs the amount. There is also an increased amount when we approach alkali works and such glass works and potteries as decompose salt. The chlorides become therefore a test both of sea water and of coal burning especially as connected with certain manufactures." (Angus Smith.)

Oxygen required to oxidize air impurities.

(Permanganate test.) If we mix a solution of

permanganate of potash* with an oxidizable substance and dilute sulphuric acid, it loses its colour and oxidizes the substances. The test imitates in the laboratory more or less the natural purification of air and speaking generally the greater.the amount of impurities in rain the more permanganate solution will be required. I have compiled the following table from the results obtained by Angus Smith and described in his classical work on "Air and Rain". It illustrates in a very remarkable manner the dependence of atmospheric impurities on locality.

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* "Condy's fluid" is permanganate of soda and behaves in a similar manner.

RELATIVE AMOUNT OF RAIN-WATER IMPURITIES.

(AFTER ANGUS SMITH.)

	Albumenoid Ammonia.	Nitric Acid.	Sulphuric Acid (Sulphates).	Hydrochloric Acid (Chlorides).	Parts by Weight Oxygen required per Million Parts Rain.
Ireland, Valencia ...	1	1	1	100	2·72
Scotland, Inland Country ...	1·15	0·83	·755	6·9	14·67
Scotland, Sea-coast West ...	3·09	1·01	1·322	25·2	1·0
Scotland, average ...	3·11	1·15	2·064	25·9	18·5
Scotland, East ...	3·1	1·29	2·806	26 5	36·06
England, Inland ...	3·21	2·02	2·022	8·2	25·89
German, specimens ...	3·59	7·81	6·007	2·7	11·22
Liverpool ...	4·67	1·57	14·502	20·9	216·44
Runcorn ...	5·59	0·75	8·652	52·9	60·55
London, 1869 ...	6·03	2 27	7·505	2·6	—
Scotland, Towns ...	6·23	3·14	6·044	12	104·39
England, Towns ...	6·29	2·33	12·553	17·9	152·39
Manchester, 1869 ...	6·38	2·39	15·26	12·1	113·89
Glasgow ...	8·82	6 72	25·71	18·4	557·78

The general lesson which this table teaches us is so clear as to scarcely require comment.

We see how pure the air over the Atlantic (at Valencia) is, but that as might be expected it is very highly charged with salt. As it passes over the land it begins to be polluted, as well as to lose its salt. The pollution increases in a very marked way in towns and apparently culminates in Glasgow.

As regards the final column which represents the result of the permanganate test, Angus Smith says:- "This I consider a very remarkable table. It includes most of the other results and gives a rough summary, like a touch of common sense, simplifying the most tangled figures."

On looking over this table it is easy to understand and to realize the physical reasons which often exist for the advantages derived from a "change of air" - especially to the sea side where the atmosphere is usually very pure and charged with salt which no doubt has a distinct and beneficial action

when inhaled.

One can also well understand why it is that the physique of workers in close and ill ventilated buildings (so many of which unfortunately exist in all large towns) is so wretched.

If we compare the sum-burned visage and broad shoulders of a sailor with the sallow complexion and hollow chests of many of our mill and factory hands, we cannot fail to appreciate the vast importance of pure fresh air and the melancholy fact must I fear be apparent, that in proportion as our manufactories increase, the physique of our population, or a section of it at all events is seriously deteriorating. No effort ought to be spared to minimize as far as possible this state of things.

We owe Angus Smith a debt of gratitude for the beautiful researches he made clearly establishing the influence of locality and surroundings on the impurities of air.

Ozone and Peroxide of Hydrogen - Although these two substances have a very different chemical composition:- one being merely an "active" form of Oxygen, while the other is a compound of oxygen and hydrogen, their chemical behaviour is so similar, that there is no really reliable method for discriminating between them. Both however appear to be present in pure air.

As regards ozone according to Andrews its volume never exceeds 1 in 700,000 of air.

It is not found in the atmosphere over towns, inhabited houses, or near marshes. There would appear to be more of it in spring than in summer, and more in summer than in autumn or winter. It is more abundant on rainy than on fine days and its presence (in the northern hemisphere) appears to be favoured by westerly and south-westerly winds Its occurrence is largely due to atmospheric electricity, its amount increasing after thunder-storms. By the evaporation of water it is also formed in small quantities, and it is said that the oxygen

which is evolved from plants contains it in minute amount. The common test which is employed to ascertain its presence in air is to expose blotting paper which has been previously soaked in a mixture of boiled starch and iodide of potassium * and dried in the dark. To make a determination the paper is exposed to the air for some hours and moistened with water, when if ozone is present, a blue colour is produced (due to the liberation of the iodine from the iodide of potassium, which strikes a blue colour with starch) Its amount can be roughly ascertained by a comparison of the tint, with a standard scale of colour.

Other tests have been suggested and used, but none up to the present time can lay any claim to scientific accuracy.

The presemce of peroxide of hydrogen in air was first demonstrated by Meissner in 1863. It is formed under many circumstances by combustion and oxidation, but in limited quantities. Indeed Schönbein states that its formation occurs in every oxidation which occurs in presence of water or aqueous

* 15 parts starch: 1 part iodide of potassium and 200 parts of water.

vapour. Schöne in Moscow found it to be invariably present in rain, dew, and snow, and that like ozone its amount fluctuates with the seasons and other conditions:- thus it appears in greater quantity in summer than in winter and its amount increases with southerly winds.

Both peroxide of hydrogen and ozone are very energetic oxidizing agents and are at once decomposed in presence of easily oxidizable substances whence their non-occurrence in the air of houses, marshes &c. where substances of the kind exist. It is quite possible that both ozone and peroxide of hydrogen play a very important part in removing impurities from the atmosphere, but at present our knowledge is too small to warrant any general conclusions regarding their functions in nature.

Dust - I have reserved this impurity as the last for consideration as it is not a pure chemical substance like the others we have dealt with but is a highly complex mixture in varying proportions. Probably however in all its forms and derived from

all ordinary sources it consists essentially of three things namely:- (1) pulverized minerals, * (2) the debris of plants and animals (i.e. dead organic matter), and (3) the minute spores or germs of lower forms of life (i.e.organic matter in a potentially living condition).

The origin of dust is almost entirely traceable to air currents and winds sweeping over the surface of the land and carrying with them the smallest and least adherent particles which they find in their track. These in virtue of their minuteness and the resistance they offer to air, may be said to float in the atmosphere, and follow its movements even to very considerable distances and often for long periods. The great volcanic explosion of Krakatoa which occurred about ten years ago caused immense quantities of dust to be projected into the atmosphere, which remained suspended for months and must have travelled far round the globe as it seems to have

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* No doubt a certain though probably a small amount of this is of cosmic origin and reaches us in the shape of meteors, which from time to time fall from space. This is proved by its containing iron as do meteorites. Nordenskiold found iron in dust covering snow and Tissandier in every kind of air.

caused in Northern Europe the remarkable phenomena noticed at the time, of intensely "red sunsets" and "blue moons".

That dust or solid particles occur in air is rendered apparent whenever a ray of sunlight enters a darkened room, for in the brightly lit up track of the ray these particles or "motes" are seen floating or as it has been described "dancing" in it - carried hither and thither by every passing current Indeed as Tyndall has shown, but for dust particles the course of the ray would be invisible. We are only just learning that these same motes are no mere plaything of nature's but that they have a very real and important significance, and that their role is of a varied kind - sometimes beneficial and at times quite the reverse. Indeed they have functions of no mean order which were never suspected by our predecessors, and are the essential factors in some of the most important of nature's operations.

The actual amount of dust in air reckoned by weight is minute. In Tissandier's experiments at Paris it amounted at maximum to about 2 parts in

100.000 and its minimum quantity was only one third as much. On the other hand the number of dust particles may be very large. We had no information on this point until within the last few years, but recently Mr John Aitken has devised a most ingenious "dust counter" with which he has already obtained some highly important and interesting results. The principle upon which his instrument is based is that if air is supersaturated with moisture, that moisture is deposited upon the dust particles, and is precipitated with each as a minute rain drop. In practice a definite quantity of air is allowed to remain in a damp chamber until it becomes saturated with moisture - then by slightly rarifying (by an air pump), it becomes super-saturated and the rain drops are precipitated on a glass plate ruled into squares to facilitate their being counted.

With this instrument, which he has perfected until it now assumes a pocket form, he has made a considerable number of observations extending over a period of two or three years. In the following table I have collected some of the many results

obtained by him, which will serve to illustrate the vast differences as regards the number of particles in air from different localities as well as their variation from time to time in number, in the same locality.

DUST PARTICLES IN AIR.

(AITKEN.)

	Number of Observations.	Dust Particles per Cubic Centimetre of Air.	
		Maximum.	Minimum.
Paris ..	4	210,000	92,000
London ...	8	150,000	48,000
Eiffel Tower ...	15	104,000	226
Hyères ..	3	46,000	725
Mentone ...	8	26,000	810
Bellagio ...	17	20,500	600
Righi Kulm ...	82	12,000	210
Dumfries ...	38	11,500	235
Kingairloch ...	161	7,600	16
Gareloch Head ...	11	1,750	51

Some of the conclusions arrived at by Mr Aitken are as follows:-

1. The earth's atmosphere is greatly polluted by dust produced by human agency.

2. This dust is carried to a considerable elevation, by the hot air rising over cities: by the hot air rising from sun-heated areas of the earth's surface, and by winds driving the dusty air up the slopes of hills.

3. The transparency of the air depends on the number of dust particles in it, and also on its humidity. The less the dust the more transparent is the air: and the dryer the air the more transparent it is. There is no evidence that humidity alone, that is water in its gaseous state and apart from dust has any effect on the transparency.

4. The dust particles in the atmosphere have vapours condensed on them, though the air itself may not be saturated.

5. The amount of vapour condensed on the dust in unsaturated air depends on the relative humidity, and also on the absolute humidity of the air. The

higher the humidity and the higher the vapour tension, the greater is the amount of moisture held by the dust particles when the air is not saturated.

6. Haze is generally produced by dust, and vapour if the air be dry, the vapour has but little effect and the density of the haze depends chiefly on the number of particles present.

7. Some of the tests made of the Mediterranean Sea air show it to be very free from dust.

8. The amount of dust in the atmosphere of pure country districts varies with the velocity and direction of the wind: fall of wind being accompanied by an increase in dust. Winds blowing from populous districts generally bring dusty air. (See Plate 5).).

The particles of dust in the air are intimately connected with various meteorological phenomena and of these the fogs of large cities are especially of interest.

London fogs are produced by the mechanical combination of particles of water with particles of coal and soot, and require for their fullest development

the following conditions:- a still air, a tempera-
ture lowest at, or near the ground in comparison
with an elevation of some hundreds of feet: satur-
ation, or partial saturation of the air with moist-
ure, within a moderate distance of the ground: ab-
sence of clouds overhead and free radiation into
space. The artificial darkness and peculiar colour-
ing occur with greatest effect at times when a very
large quantity of coal is burnt in domestic fire
places. (Nature vol. 39)

"The formation of a London fog appears to take
place as follows:- An ordinary thick white fog
covers the city, say at 6 a.m. about a million fires
are lighted soon after this hour and the atmosphere
becomes charged with enormous volumes of smoke, i.e.
the gases of combustion bearing carbonaceous parti-
cles. Now these particles as soon as they are
cooled to the temperature of the air, or below, begin
to attract to themselves the water spherules already
present and visible, and vapour may also be condensed
on the particles. A thick layer of these united
particles prevents light from penetrating it, and a

very small quantity of finely divided carbon may stop the brightest sunshine altogether, like the film of soot on a smoked glass. The absence of light must tell decidedly on the vital force of the community taken as a whole" (Nature)

Then too we find the quantity of carbonic acid rising to a very high amount - to as much as 10 volumes in 10,000 of air. Sulphur compounds - especially sulphurous anhydride, are often distinctly apparent in the fogs of some towns, notably Manchester, and are extremely irritating to the lungs, so that we are quite prepared to learn that the fogs which are prevalent during the winter in large cities are very harmful to human beings.

"In the great fogs of 1880 the death rate of London rose from 27.1, for the week ending January 24th, to 48.1 for the week ending February 7th:- which was the period of thickest fog.

In the period of three weeks from January 24th to February 14th, the excess of deaths over the average in London was 2,994. Probably ten times as many were ill, from the combined effects of smoke

and cold. The moral reaction of this atmosphere is well worthy of consideration. If smoke were got rid of there would be a great revival of plant vigour and human gaiety." (Nature.)

The actual cost of these dark fogs to active human workers:- irrespective of the cost to those who are stricken down, is another point well worthy of consideration. Excluding the loss through stoppage of traffic &c. each London fog costs it is stated in gas alone for illumination £5,250. It has been repeatedly urged that some very drastic measure should be taken for preventing the huge volumes of smoke which are thrown out from the chimneys of our dwellings and factories - the main factor in these dark fogs - from making their escape into the air, but legislation on the subject would be extremely difficult.

Turning now to the nature of dust, we have seen that it contains in addition to pulverized minerals and the debris of plants and animals, the spores or germs of living organisms. The latter are exceedingly minute, but they are nevertheless capable of

producing effects on a vast scale, and that they play a very important role in nature is now a well ascertained fact.

Putrefaction and decay - which are really devices of nature's for disposing of dead organic matter and for converting it into substances which can again serve for the nourishment of plants and animals - are caused by some of these organisms, while others have equally well defined but totally different functions. Thus there is a set of organisms which have the power of inducing perfectly definite chemical changes in certain substances, and unconsciously they have been employed from time immemorial for the purpose. Among these is yeast, which converts sugar into alcohol and carbonic anhydride; and the organism which causes the production of vinegar or acetic acid from fermented liquids. The souring of milk is due to another species, and the production of saltpetre is the work of a fourth. Others again cause the formation of various colouring matters, and some of these have at times excited the awe and wonder of the superstitious. For instance

there is the phenomenon of the "Bleeding Host" when bread has apparently become covered with blood. But far more important than any of these are the organisms which are the undoubted causes of certain diseases often the worst and most malignant to which men and animals are subject. The study of these micro-organisms as they are sometimes called, has thus opened up a very wide field of research and has thrown a flood of light on many phenomena, the causes of which were formerly hidden in mystery. It has also led to practical results of no mean order. Thus the brewer and distiller no longer work empirically but are guided in their various processes by scientific considerations and as a consequence work under more economical conditions. For the first time in the history of medicine a rational theory of the nature and causes of infectious and contagious diseases has been introduced, with the result that attempts have been made to combat these maladies in a new way and to protect men and animals from their ravages. These attempts - although the subject is quite in its infancy - have in the hands of Pasteur

and others led, already to remarkable and important consequences and it seems probable that with the progress of time further advances will be made in the same direction.

As the subject of micro-organisms is of great interest I have added an appendix in which it is discussed more fully. (See Appendix "F".)

Having considered the composition of the air and the nature and source of its impurities I pass now to the subject of its vitiation by human beings and the means which are employed for securing to them a proper supply of fresh air.

Every adult man uses up about 20 cubic feet of oxygen and exhales about 16 cubic feet of carbonic acid in twenty four hours,* along with a quantity of water variously estimated at from 7 to 22·5 ounces. By exhaling that amount of carbonic acid he vitiates

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* This quantity is however subject to considerable variation depending chiefly upon the amount of exercise he takes, or work he has to perform. In repose it is only about 14·4: in gentle exercise 21·6: and during hard work it may reach 43·2 cubic feet - with a corresponding consumption of oxygen.

about 400 cubic feet of air. A candle produces three quarters of the amount of carbonic acid which a man does, and a strong oil or gas lamp about five times as much.

There are however other sources of air pollution in inhabited buildings, notably the organic matter evolved from both the lungs and the skin. As to the former, the composition of exhaled air may be stated as being -

	Per cent
Oxygen	16·033
Nitrogen	79·557
Carbonic acid	4·380
Ammonia	traces
Hydrogen	trace
Marsh Gas (Methane)	trace
Unknown organic matters	?
Aqueous vapour	nearly to saturation

while as regards the latter the quantity of perspiration evolved from the skin is very large and may be taken as amounting on an average to about two pounds from an adult in twenty four hours & containing 1·2 per cent of organic substances.

The inhalation of these organic matters appears to be very injurious to health. Then in ordinary

buildings there is dust, which as we have seen contains large numbers of micro-organisms.

Tha air of inhabited buildings is thus contaminated with solid, liquid and gaseous impurities, both inorganic and organic, dead and living: some derived from the occupants, some from the means adopted for warming and lighting ,and some from the building itself.

Some idea of the actual quantity of air used up by a number of human beings, and the quantities of noxious impurities they produce may be formed from the statement that during a two hours meeting 2,000 people will give off about 17 gallons of water and as much carbonic acid as would be produced bby burning a hundredweight of coal. So that unless good ventilation exists, the air in a crowded room soon becomes poisonous.

It is generally held that to ensure healthy respiration each person should have at least 3,000 cubic feet of air per hour - this standard being based upon the principle that the quantity of carbonic acid should not be increased in the air by more than

about one half its normal amount. According to de Chaumont this is the point at which there is no sensible difference between the air of an habitated space and the external air as determined by the sense of smell. For an ordinary gas burner from 5400 to 9000 cubic feet of air are allowed.

"The amount of fresh air required per head having been agreed upon according to the foregoing considerations, the answer to the question of how much cubic space is needed will depend upon the ease with which the air in the air space can be renewed.

The larger the room, the less frequently need the contained air be displaced by fresh air from the outside: the smaller the room the more often must this change take place, and the greater is the difficulty experienced in doing this effectually without causing draught. In an air space containing 1000 cubic feet per head the air needs only to be

changed three times per hour to provide the necessary 3000 cubic feet: but if the space is not more than 500 cubic feet, obviously six changes per hour are required to supply the same quantity of fresh air. With the best mechanical means of ventilation even this can be effected without perceptible draught as in Pettenkofer's experimental room at Munich, where 2,640 feet of air are drawn hourly by a steam engine through a space of 424 cubic feet. But in temperate climes and under ordinary circumstances three changes per hour are all that can be borne: more frequent change than this produces cold currents of air and draughts. Therefore for sleeping apartments generally 1,000 cubic feet per head should be allowed: in the case of old people and children so large a space is not necessary - probably 500 to 600 cubic feet would be sufficient. These dimensions are higher than are usually allowed, but as Dr. Parkes says "after all the question is not what is likely to be done: and it is an encouraging fact that in most things

in this world, when a right course is recognised, it is somehow or other usually followed." (Notter.)

The ventilation of an ordinary room depends upon the entrance of fresh air through door or windows (or through the crevices between them and their frames when they are closed) while the foul air escapes up the chimney: and therefore rooms without chimneys and with double windows or with the register of the grate closed, are unhealthy.

Ventilation also occurs to a certain extent spontaneously through the walls of a room, if they are not painted, for bricks, mortar and plaster are porous and as the particles of air (and indeed of all gases), are in a state of perpetual movement, there is a constant stream of foul air outwards and of fresh air inwards even when the external air is still. Pettenkofer showed years ago that an ordinary brick is so porous, that if enclosed in the centre of a chamber - air blown in through a hole on one side will pass through the brick and out of a corresponding hole on the other side with but

little diminished force.

It is indeed quite conceivable that the ideal of ventilation - so far at least as the absence of draught is concerned - would be secured in a room, merely by having very thin porous walls exposed on all sides to the air, so that the vitiated air would escape and the pure air enter entirely by diffusion. But in practice serious difficulties in ventilation are met with owing to economic conditions which demand that both in labour and amusement large numbers of individuals shall be crowded into small spaces. It must I think strike the most casual observer that in the majority of our factories, workshops and places of business, as well as our theatres and other places of amusement - the ventilation as a rule is imperfect owing to this reason. It is a question of foul air <u>versus</u> draughts and humanity on the whole seems to prefer the former to the latter.

To avoid draughts Tobins' system of ventilation is of great service. It consists in

admitting fresh air through vertical tubes about seven feet in height which are fastened to the wall inside a room, and communicate with the outside at the level of the floor. Fresh air passing from the outside through these tubes into the room, is projected upwards and falls slowly downwards. Thus if suitable means are adopted for drawing off the foul air (which in virtue of its higher temperature rises) - through openings at the top of the room, the air is renewed above the heads of the occupants and currents and draughts are avoided at lower levels.

That the breathing of impure air is very injurious to health, is a fact now well known and generally acknowledged, and many statistics have been collected on the subject. Thus it has been shown that respiratory diseases of various kinds are induced by dust inhaled by workmen engaged in certain trades, as the following table proves.

Comparative Mortality.

	Phthisis	Respiratory Disease
Males (England & Wales)	220	182
Earthenware Manufacturies. . . .	473	645
File Makers.	433	350
Miners (in Cornwall)	690	458
Printers	461	166

"Hay Fever" is caused in susceptible persons by the pollen of certain flowers inhaled with air: and there can now be no question that many infectious diseases are communicated by the inhalation of minute particles which are really the spores of vegetable organisms. The inhalation of air rendered impure by respiration may cause a variety of unpleasant symptons such as heaviness, lassitude, headache and nausea; the poisonous agents being apparently organic matter evolved from the skin and lungs: or its effects may be much more serious in very confined places leading to actual death. Persons who are compelled to breathe even a mildly vitiated atmosphere of this kind become pale, lose flesh and appetite, and are especially

liable to phthisis. This latter has been proved again and again by the diminution in death rate from that disease which has occurred after improved ventilation among a community, other conditions being unaltered. The respiratory organs in especial are rendered delicate by breathing the air of close places: Thus,"in the Afghan war, pneumonia was very prevalent and fatal in the overcrowded barracks, while there was not a single case among those in tents: distributing the men in tents had the effect of at once stopping the disease."

In the case of breathing the gases emanating from drains and sewers it is the digestive system which mainly suffers. Effects such as headache, vomiting and great prostration are frequently produced. And it has long been recognized as an established fact that certain specific diseases, of which enteric or typhoid fever, diphtheria and diarrhoea, are the chief, have a very intimate connection with the inhalation of sewer gases.

After it had been proved that infectious diseases are caused by micro-organisms, (which presumably occur at times in the atmosphere), it seemed natural to suppose that the germs of the organisms (which undoubtedly are the active causes of the diseases in question) would be found in sewer gases. On the contrary however, it has been demonstrated conclusively that these gases are singularly free from organisms of all kinds.

Quite recently light has been thrown upon the subject by Alessi by means of experiments on animals.

For this purpose the effect of inhaling sewer air and the gases from putrefying matter was examined on rats, rabbits, and guinea pigs. After exposing them to sewer air they were inoculated with a small quantity of only a slightly virulent cultivation of the typhoid bacillus while other animals were similarly treated, except that they were not compelled to inhale the noxious gases, but were kept in their ordinary surroundings. Of 49 rats who had inhaled the sewer gas previous to inoculation, 37 died exhibiting the typical symptoms of typhoid

infection, while all grew thin and lost their vivacity. The guinea pigs and rabbits exposed in like manner also acquired a predisposition to typhoid infection and out of 72 of the former inoculated, 57 died, while not one of those teated with typhoid germs in their ordinary surroundings succumbed. Every one of the 11 rabbits similarly treated died, but not a single one of the inoculated animals who had not been exposed to an atmosphere of the foul gases. Alessi found moreover that a small dose of a weakened culture of an organism normally present in the intestine (Bacillus coli communis) produced fatal results when purposely introduced into animals which had inhaled sewer gases.

It was also ascertained that it was during the first two weeks of exposure to these noxious gases that the animals were most easily predisposed to typhoid infection:for no less than 90 per cent of all animals inoculated during the first fortnight died, while but 76 per cent succumbed of those inoculated in the third week.(Nature 1894) It is thus shown that the inhalation of sewer gases acts merely as

the predisposing cause of the disease, by lowering the system in some way so that the typhoid organism (which is probably more prevalent than is commonly supposed), finds a suitable soil or nidus, upon or rather in which to grow; and that but for this cause they would either not enter the system at all, or at all events not take root in it - so to speak. On the other hand if the sewer gases are inhaled for considerable periods of time, the system gradually recovers its natural powers of resistance. In this way we may account for the fact that men working in, or about sewers do not suffer unduly from typhoid - and possibly also explain why it is that people after a holiday are attacked by the disease on their return to an unhealthy home. It is probable that similar considerations may apply to other diseases - in a measure at all events - notably to phthisis - a predisposition to which seems to be acquired by inhaling the air of very close places.

In connection with this subject mention ought to be made of the beautiful theory of Phagocytosis advanced by the Russian savant Metchnikoff and

supported by many observations of a highly important kind.

There occur in the blood and in some of the other fluids bathing the tissues of the living body certain colourless cells to which the name of leuco cytes has been given. These have quite an individuality of their own, extending to the power of independent locomotion, digestion and to some faculty almost akin to intelligence. If foreign particles are introduced into the blood, they are enveloped by the leucocytes and if capable of assimilation they are absorbed by the latter. These leucocytes serve in fact as scavengers of the blood and remove its impurities by feeding upon them. But according to Metchnikoff they have even more important functions and serve as protectors against the invasion of micro-organisms. No sooner do these enemies of the body effect an entrance at any point than the leucocytes collect round them in large numbers and then a regular combat ensues in which sometimes one side and sometimes the other gains the victory. If the leucocytes succeed in the struggle the org

organisms are devoured and the animal owning these useful guardians escapes serious injury. But if on the other hand the micro-organisms prevail, (and the theory is that they do so by means of a poison they secrete which protects them from the leucocytes) then disease of the animal and it may be its death supervene.

Assuming that this theory is correct, we can readily understand that the activity of the leucocytes must depend upon the nature of their surroundings - which means the condition of the blood, and as the latter is constsntly bathed in air, atmospheric impurities must necessarily exercise a vast influence in the matter of health.

Appendix A

A new constituent of the atmosphere.

At the meeting of the British Association held at Oxford in the present year (1894), much interest was caused, and even excitement in scientific circles, by the announcement by Lord Rayleigh and Professor W. A. Ramsay, that they had discovered a new substance in the atmosphere.

It would appear that certain experiments of Cavendish pointed to the presence in air of some body other than its ordinary gaseous constituents, But Lord Rayleigh's attention was first drawn definitely to the subject by the differences he found in the densities of "atmospheric" and "chemical" nitrogen: that is to say between the density of nitrogen as extracted from air, and obtained by chemical processes from its compounds. This observation induced him in collaboration with Ramsay to submit the matter to closer examination, and although the results which have so far been made

public are somewhat meagre, it appears certain that in addition to nitrogen there is present in the atmosphere another and even more inert gaseous constituent, though in smaller amount. The following is a brief resumé of what has been ascertained - or at all events published-up to the present time regarding the new substance.-

What has hitherto been considered as pure nitrogen is obtained as we have seen, by passing air (free from carbonic acid) over red hot copper, which removes its oxygen. A similar result follows if air is treated with phosphorus or with a solution of pyrogallic acid mixed with an alkali. If this "atmospheric" nitrogen be passed over heated magnesium, the pure nitrogen is absorbed and the new gas remains. Its quantity appears to be close on 1 per cent of the nitrogen of air and therefore about 0.2 per cent of the air itself, which is between five and seven times the quantity of the carbonic acid - the only gas hitherto recognised as a normal constituent of air in addition to its chief components oxygen and nitrogen.

The new gas is colourless and odourless, of density 19.1 - (subsequent determinations give 20.3 and quite consistently). It is unacted on by red hot magnesium, by electric sparks or discharge in presence of oxygen and potash or soda:- reactions which serve to separate the nitrogen in air from it. Its solubility is about 4 volumes in a 100 of water. It can be separated from air by diffusion and also by fractional solution of its mixture with atmospheric nitrogen. It possesses a characteristic spectrum containing a large number of lines. It is specially remarkable for its great inertness.

Professor Ramsay has very kindly supplied me with some of the above facts and he has also mentioned other particulars which for the present I am not entitled to disclose.

There can however be no objection to my saying that he has isolated the new substance in considerable quantities in the pure condition and that he hopes in the course of a few weeks that matters will be ripe for the publication of fuller details.

In the mean time we cannot say whether or no

this new substance is a hitherto unrecognised chemical element (or undecomposable body) - or merely nitrogen, or a known element in an allotropic condition. But it can scarcely be a compound.

If it be a new element, then by analogy its atomic weight should be one half its density (referred to hydrogen) say 10 or thereabouts, and from a chemist's point of view such an element -especially if a gas is hardly conceivable.

Appendix B

Commercial Manufacture of Oxygen.

Oxygen is now prepared in large quantities and is forcedinto strong steel cylinders under great pressure, thus avoiding the use of the bulky "gas bags" of former days and the clumsy apparatus of pressure boards and weights which had to be carried about and used with them. By this means large volumes of the gas are stored in a small space and in a portable apparatus which may be carried easily from place to place, the gas being available at any time for use merely by unscrewing the valve attached to the cylinder, when it issues in a stream which can be easily regulated for any desired purpose.

Owing to the fact that oxygen has now become an article of commerce (mainly for the production of the "Lime Light") various methods have been suggested for obtaining it cheaply.

For laboratory purposes it is generally prepared by heating chlorate of potash with a small

proportion of peroxide of manganese, when the chlorate loses or gives up the whole of its oxygen at a comparatively low temperature. Formerly this process was employed on a large scale but now cheaper methods are resorted to.

The first of these was by heating ordinary nitre or saltpetre, and this method in various modifications has formed the basis of several patents. In fact it is the subject of the first oxygen patent taken out in Great Britain in 1849.

Then by heating peroxide of manganese alone, oxygen is evolved, and until recently it formed one of the cheapest and most economical methods.

But as air contains about 21 per cent by volume of oxygen, and water about 11 per cent by weight, it was only natural to seek in these substances economic sources of the gas. A great many processes have been suggested for the purpose and some have been patented. It will be sufficient to describe only those of special importance. The original method by which Priestley obtained oxygen - namely by heating the red oxide of mercury - is in reality

one for obtaining the gas from air: for if metallic mercury is heated in air at a temperature approaching its boiling point it combines with oxygen and forms oxide of mercury and the latter when heated more strongly gives up its oxygen and metallic mercury is reproduced. But this method is only of theoretical interest.

A very simple process is based upon the fact that oxygen is more soluble in water than nitrogen, and therefore when air is forced into water under pressure a solution of oxygen containing a relatively small proportion of nitrogen is obtained, and when the pressure is released the unabsorbed nitrogen escapes. If the dissolved gases are then extracted by exhaustion and submitted to the same treatment again, a solution richer in oxygen is obtained and by repeating the process eight times in all, nearly pure oxygen may be obtained. Tessie du Motay suggested a process which for some time was carried out on a large scale and seemed to promise well. It consisted in passing air over a heated mixture of

caustic soda and peroxide of manganese when oxygen is absorbed. Then by passing steam over the heated product(Manganate of soda), the oxygen is given off and the original substances reproduced. By thus alternately passing air and steam over the heated mixture of caustic soda and peroxide of manganese, oxygen was readily obtained in quantity: but although the process seemed to promise well, it did not succeed ultimately, as in practice the yield of oxygen was found to gradually diminish. Passing over several other processes of minor importance we come to the method discovered by Boussingault in 1851, and improved and perfected by the Messrs. Brin who took out a British patent in 1880. This process at first defective has been greatly improved and is now carried out on a large scale - most of the oxygen supplied for commercial purposes (in the British Isles at all events) being produced by its means.

In its original form the method consisted in heating the monoxide of barium in a stream of air, when that compound absorbs oxygen and forms the peroxide: then by heating the latter to a higher

temperature (with the air supply cut off), it is resolved again into the monoxide, while oxygen is evolved. Thus by alternately heating Baryta in air and the resulting peroxide to a higher temperature by itself oxygen is obtained. But in practice it was found that after a few operations the baryta lost its power of absorbing oxygen. As at present performed the process is free from this objection mainly owing to a modification whereby changes of temperature are avoided and changes of pressure substituted instead. Air (carefully purified)is pumped over heated baryta at a pressure of from 10 - 15 lbs. on the square inch. Under these circumstances oxygen is absorbed by the baryta and atmospheric nitrogen remains. The latter is removed by reversing the pumps: then when the pressure falls sufficiently, the peroxide of barium decomposes (without change of temperature) and pure oxygen is evolved. This is drawn off and stored. The same cycle of operations is then repeated, and in this way the same baryta remains efficient for months, and the process is a success commercially.

As regards the manufacture of oxygen from water, there is a single method which can be employed, and that is by decomposing it by electricity. If the wires coming from a galvanic battery or a dynamo machine are connected with platinum plates dipping beneath the surface of water, which has been acidulated (best by adding some sulphuric acid) - oxygen is disengaged from the plate connected with the positive wire and hydrogen from the plate connected with the negative wire, and the two gases are practically pure. The economic aspects of the process depend upon the conditions. Both hydrogen and oxygen are obtained in the process and both are required for the lime light. Moreover no pumping apparatus is required for compressing them, as they may be forced into the steel cylinders for their reception merely by connecting the apparatus from which they are disengaged, with the cylinders, (if the generating apparatus is enclosed in a sufficiently strong vessel). The cost of production is therefore almost entirely dependent on the cost of power and the wear and tear of machinery.

The installation of the necessary machinery having once been made in a locality where water power is abundant, it ought to be possible to produce oxygen (and hydrogen) very economically and it therefore seems probable that this method will eventually be largely employed.

As regards the cost of production, the following figures have been given by L.T. Thorne for 1000 cubic feet of the gas.

From chlorate of potash . . .	£8	-	£10
From peroxide of manganese (alone)	£4	-	£ 6
By the Tessiè du Motay process	£3	-	£ 4
From sulphuric acid. . . .	£2:10	-	£ 3
By the electrolysis of water	25/-	-	30/-
By the Brin process	3/-	-	7/-

Appendix C

Liquefaction of Oxygen, Nitrogen and air.

It has been known since the year 1806 when Northmore liquefied chlorine, that many gases can be reduced to liquids by pressure. We are indebted to Faraday for much of the early work done in this direction. The method which he employed, at first consisted in sealing up in one limb of a bent glass tube substances which either by their action on each other, or when heated, generated the gas, which being in a confined space produced sufficient pressure to cause a portion of it to be condensed in the liquid state - the liquid separating in the other limb of the tube purposely kept cold. In this way he liquified a number of gases such as sulphurous and carbonic acids, nitrous oxide, ammonia, cyanogen and hydrochloric acid. In later experiments Faraday employed a compression pump to produce the necessary pressure.

But there were a number of gases which Faraday found it impossible to liquefy, such as nitrogen, hydrogen, oxygen, marsh gas, carbonic oxide &c., these were in consequence termed permanent to distinguish them from those which could be liquefied and which were called coercible.

Faraday made the discovery that many gases would also assume the liquid condition if submitted to cold only. In this way sulphurous acid liquefies when cooled to - 10°c. and cyanogen at - 21°c. Andrews in his classic researches on the Continuity of the Liquid and Gaseous States showed in 1869 that temperature plays a very important part in the liquefaction of gases and that they refuse altogether to pass into the liquid condition (even when submitted to enormous pressure) if the temperature is sufficiently high. In the case of carbonic acid he found that this temperature is sharply defined and amounts to 30.92°c. He called it the critical point and subsequent researches have shown that for every gas there is a perfectly definite critical point or temperature at, or below which it may be

made to pass into the liquid state by pressure, but above which it cannot be made to do so, no matter how great the pressure applied to it.

Although Faraday had expressed the opinion that the so called permanent gases would be found to be liquefiable if submitted to sufficient cold and pressure, and although Andrews had subjected some of them to a pressure of 500 atmospheres and to cold amounting to more than - 100°c., (while Natterer had employed the enormous pressure of 2750 atmospheres) all efforts to effect their liquefaction were fruitless until 1877.

In that year Cailletet and Pictet quite independently of each other succeeded in liquefying nitrogen and oxygen and as they believed hydrogen also.

Cailletet's method was based chiefly upon the refrigeration which occurs when a compressed gas expands. By submitting oxygen to a pressure of 300 or 400 atmospheres and then suddenly releasing it from pressure, the result was to momentarily lower the temperature of the gas below the critical point

and liquefaction occurred. Pictet proceeded on different lines. He, like Faraday obtained the necessary pressure by producing oxygen in a confined space. He then cooled the gas in this condition by surrounding the vessel containing it with liquid carbonic acid boiling in vacuo, whereby the temperature was reduced to - 140°c. When the stopcock at the end of the vessel containing the oxygen was opened, the liquefied gas issued in a jet.

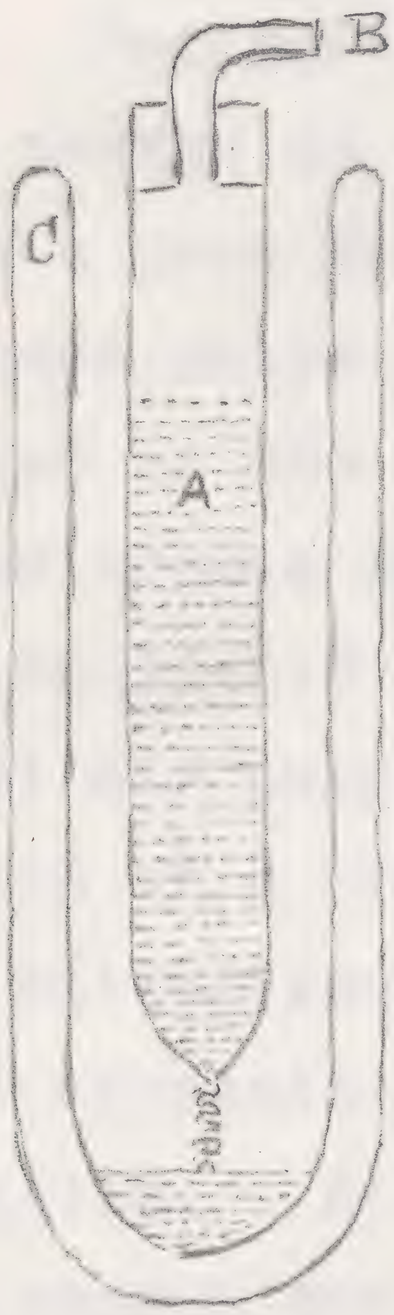
Recently Dewar by means of elaborate and costly-machinery erected for the purpose at the Royal Institution has obtained liquid oxygen and nitrogen in very large quantities (more than a pint at a time) and by placing them in glass vessels with double sides- the space between these sides being in a condition of high vacuum- he has kept them under observation for several hours at a time, and has made a thorough study of their properties. He has also liquified air as such, in quantity and has made many interesting observations on it. The exact nature of Dewar's apparatus for effecting the condensation of oxygen in large quantity, has not I believe been

made public, but in writing to a correspondent he has made the following statement:-

"The process briefly speaking is this, Into the outer chamber of that double compressor I introduce through a pipe, liquid nitrous oxide under a pressure of about 1400 lbs. to the square inch. I then allow it to evaporate rapidly and thus obtain a temperature round the inner chamber of - 90°c. Into this cooled inner chamber I introduce liquid ethylene, (which is a gas at ordinary temperatures), under a pressure of 1800 lbs. to the square inch. When the chamber is full of liquid ethylene, its rapid evaporation under exhaustion reduces the temperature to - 145°c. Running through this inner chamber is a tube containing oxygen at 750 lbs. pressure to the square inch. The critical point of oxygen i.e. the point above which no amount of pressure will liquefy it, is - 115°c. but this pressure is amply sufficient to cause it to liquefy rapidly. In drawing off the liquid under this pressure I lose 9/10 by evaporation."

In order to obtain liquid air Dewar employed a

very simple device shown in the sketch below.



A is a tube closed at the bottom and partly full of liquid oxygen. It is connected with an air pump by the tube B so that it may rapidly evaporate under diminished pressure. C is a tube with double walls the space between them being in the highest condition of vacuum possible to obtain: the space between this tube and that containing the boiling liquid oxygen is full of air, which liquefies <u>on</u> the oxygen tube in consequence of the intensely low temperature of the latter (about - 200°c) and drips into the outer tube.

Liquid air boils at - 190°c, giving off substantially pure nitrogen, as oxygen boils at a temperature some 10°c. higher: after some time the liquid alters its composition and boiling point, and finally pure oxygen is left - thus affording another and convincing

proof that the air is merely a mixture of these two gases. During the ebullition, liquid air also suffers a change in colour passing from a very faint blue to a much deeper shade, for liquid nitrogen is colourless while oxygen is blue. If liquid air collected in the above manner in a vacuum vessel is isolated from a rapid heat supply by immersing the vessel in liquid oxygen and then connected with a powerful air pump, after a time it passes into the condition of a clear transparent block of ice. Nitrogen solidifies under such conditions into a white mass of crystals, but all attempts to solidify oxygen have failed. At such low temperatures as boiling liquid oxygen and air, ordinary combustion ceases, a glowing match refusing to burst into flame if immersed in the former: but burning sulphur under the same conditions continues its combustion. Liquid oxygen is strongly magnetic.

In conclusion it may be mentioned that while all the other so called permanent gases have been liquefied, Hydrogen alone remains uncondensed. Its critical temperature is therefore the lowest of all known substances.

Appendix D

Air in its relations to Energy

When an ordinary combustible burns in air, chemical actions occur whereby the carbon and hydrogen of the burning substance unite with the oxygen of the air forming carbonic anhydride and water respectively.

These are the sole ponderable products of the change, but there are other products which though not ponderable have quite as real an existence and an equal importance. These imponderable products are heat and light, which are now spoken of as "Forms of Energy."

The nett result of all investigations into Nature by means of Physical Science has been to show that in the Universe there are two great factors, namely, Matter and Energy. By the term Matter, is understood everything whether solid, liquid, or gaseous. It is usually defined as being all that which has weight, or which obeys the laws of Gravity.

It has been proved that matter is uncreateable and indestructible by human means, and so far, chemistry has shown that all known forms of matter result from some 70 or 80 primal substances or elements which cannot be decomposed nor converted into each other. Most of the ordinary substances we are acquainted with result from the combination of two or more of these elements (as a rule not more than four). It is more difficult to give a precise idea of Energy. It has been defined as the power of doing work or of overcoming resistance, also as the cause of motion. Like matter it can neither be created nor destroyed. Energy exists in several different forms of which the chief are, Motion, Heat, Light, Sound, Electricity, and Chemical Action. These different forms of Energy are rendered manifest by their actions on matter, producing phenomena which are apparent to our senses, and it is in this way that we recognise them.

Chemists have never succeeded in transforming the ultimate constituents of matter- the elements as they are called - into each other though it was

the aim of the alchemists to effect such transformation (at least in the case of the metals). On the other hand modern science has shown that in the case of Energy not only are its different forms capable of transformation into each other, but that such changes are constantly occurring around us.

Take for instance a falling stone striking the earth. Apparently its energy vanishes as its motion is arrested, but this is not really the case for investigation proves that both the stone and the spot of ground struck by it, are warmer than they were before;- in other words, heat is produced, and here we have an example of the transformation of the Energy of motion into that of Heat. In all similar cases where energy apparently vanishes it does not do so in reality, but is simply changed into other forms which may and often do, escape recognition. The relation of one form of energy to another is not only qualitative but is also quantitative: a certain amount of one form being equivalent to a fixed and definite amount of another. The "Mechanical equivalent of Heat" as it has been called has been

carefully determined by Joule and others and may thus be expressed "In order to heat one pound of water one degree Fahrenheit 772 foot pounds of work must be expended." This means that if the whole of the energy developed by a mass of any substance weighing one pound falling through a height of 772 feet were transformed into heat, the amount of the latter would be just sufficient to raise the temperature of one pound of water, one degree Fahrenheit - or conversely the heat given out by a pound of water cooling through one degree Fahrenheit would if converted into work be just sufficient to raise a weight of one pound through a height of 772 feet.

Similar quantitative relationships exist between the other forms of energy. In addition to its transformations there are other properties of energy of especial interest. One of them is that it can exist in both a passive and an active condition. In the former it is spoken of as "Potential", while in the latter it is called "Kinetic". A stone thrown upwards acquires during its ascent

a store of potential energy: as it falls, the energy becomes Kinetic. In the same system as the one kind of energy is gained the other is lost and vice versa. Take the case of a pendulum. As it rises to one side, its energy becomes more and more potential until its highest point is reached when all is potential. As the pendulum falls its energy gradually changes from the potential to the kinetic state until its lowest point is attained when the whole is kinetic. As it ascends on the opposite track kinetic energy is gradually lost and potential energy gained until the highest point is again reached when the whole of the energy is once more potential: and as the pendulum falls once more, the same cycle of energy changes is repeated.

Changes of potential into kinetic energy and vice versa are constantly occurring around us and two of the most important factors in inducing these changes are the oxygen of the air on the one hand and the radiation of heat and light from the sun on the other.

In the case of an ordinary combustible burning

in air we have seen that heat is produced and this is a kinetic form of energy. The heat is caused by the combination of hydrogen and carbon contained in the combustible with the oxygen of the air, so that both the combustible and the oxygen may be considered as charged with potential energy which is converted in the act of their union into kinetic energy. In the steam engine heat is converted into motion and it is in this way that the energy we make use of for practical purposes in our factories, railways and steam ships is obtained.

When an animal breathes, a change or changes similar in character to the combustion of fuel occur. The oxygen of the air combining with part of the carbon and hydrogen of the food, forming ultimately carbonic anhydride and water. This combustion-- for combustion it really is - takes place at a far lower temperature than the corresponding phenomenon with fuel, and no light is produced but heat is developed and is conveyed through the body by the blood vessels, which thus function like a system of hot water pipes in warming and keeping the interior of a building

at an equable temperature. It is in this way that warmth is produced and distributed in the bodies of animals. But further, the movements of an animal are also due to the energy produced by the chemical action which occurs between the oxygen of the air and the constituents of the food. Whenever a muscle contracts and work is done, as for instance when an animal walks or runs, that contraction is associated with an increased excretion of carbonic anhydride and other products, denoting an increased chemical action and ultimate consumption of food. In this case the energy arising from the chemical processes appears to be converted (partly at least), directly into the energy of motion without intermediate transformation into heat and thus the body of an animal although performing the same functions as a steam engine in transforming chemical energy into work is a more perfect and probably a more economic transformer than the latter as only a small proportion of the heat generated under the boiler of an engine is transformed into work, the rest escaping unaltered-partly by radiation and partly in the hot

steam. In fact in the most economical steam engines at most 16 per cent of the heat of the fuel is converted into mechanical energy.

From what has been said the air, - or rather the oxygen it contains, must be regarded as a vast store house of potential energy from which constant supplies are being drawn off by animals for their vital processes and by human beings not only for those purposes but also for what may be termed the purely artificial phenomenon of ordinary combustion which is utilized partly as such for warming and lighting houses, and partly by conversion into mechanical energy by the steam engine. In proportion then as oxygen is lost from the air by these processes, the stock of available potential energy of the world is diminished; but here plants come to the aid of animals as they decompose carbonic anhydride and water restoring oxygen to the air and absorbing carbon and hydrogen, out of which they form their tissues. Thus the functions of plants and animals and their actions on air are reciprocal. For the substances formed by plants serve as food for animals, while

the oxygen which the plant exhales may equally be considered in the light of an animal food stuff. These products of plant life are again ultimately converted by the animal into carbonic anhydride and water - the same simple substances which serve the plant as food.

The reciprocity of functions goes however further than this, and embraces not only chemical changes but what may be called energy reactions also. For animals as we have seen convert the potential energy which is stored up in atmospheric oxygen and the materials of food, into kinetic energy which appears as heat and motion. The chemical products of this reaction are devoid of available energy, quite as much as a stone which has fallen. Plants perform with the water and carbonic anhydride an operation which so far as energy is concerned is strictly comparable with raising the stone. For just as by the latter operation a charge of potential energy is imparted, so with the decomposition of the carbonic anhydride and water - the substances absorbed by the plant and the oxygen returned by the latter to the air.also

represent potential energy, which can be utilized again by the animal or changed into kinetic energy by ordinary combustion. But what is the source of the potential energy of the plant ? It cannot have been derived from nothing and no energy is conveyed by by its food. The answer is simple. Plants only decompose carbonic anhydride and water in sunlight. In the act of decomposing these two they absorb kinetic energy from the sun's rays which they convert into potential energy. So far then as energy is concerned it is the function of animals to use up potential energy which is stored in atmospheric oxygen and in plants respectively, and to convert it into the kinetic form which is ultimately frittered down into heat. Plants on the other hand make use of the kinetic energy of the sun's rays to reverse the process and to store up energy in the potential condition.

If we consider movements occurring on the surface of the earth, and the various transformations of energy which take place, in addition to those connected with life we are led to the conclusion that

with very few exceptions such as the tides and the heat of volcanos , all our store of useful energy is ultimately derived from the sun. It is the cause of winds which propel our sailing ships, of rain, and consequently of rivers which we utilize as a source for water power. It too gave us coal which we employ as a fuel. So long then as the sun continues to radiate sufficient heat and light these processes will continue, and animal and vegetable life will flourish on the globe. But in addition to its conservation and its transformations Energy has one other remarkable property which has been called that of its "Dissipation" or more aptly "Degradation". Of the various forms of energy some are more capable of being transformed than others and every time a transformation takes place there is always a tendency to pass, in part at least, from a more available or higher, to a less available or lower, form - so that although theoretically a definite amount of one form of energy can be transformed into an equivalent quantity of another, such complete transformations rarely occur, as they require conditions

almost impossible to realise.

In the case of the steam engine only a small fraction of heat is converted into mechanical energy the remainder is "let down" so to speak from a higher to a lower temperature without undergoing transformation. The heat of a very hot body can be much more readily converted than the same amount in a colder body; so that although a definite amount of heat corresponds with its equivalent of work no matter what its condition may be, yet its availability for conversion is different under different circumstances. In order to get any work at all out of it, it is necessary to have a hotter and a colder body, but if all the energy of the Universe were transformed into heat and that heat were uniformly diffused (throughout the Universe), so that all things were at the same temperature, then it would be impossible by any process with which we are acquainted to raise the smallest part of that heat into a more available form of energy.

But in Nature this is the very thing which seems to be occurring - that is to say the gradual

frittering down of the higher forms of energy into equally diffused heat. The time must therefore arrive when life, motion and all other phenomena will cease.

Appendix E

The Degradation of Matter

It has been shown that there is a tendency in Nature for the more useful or available forms of energy to pass into less useful or available forms and that eventually in the far future the whole energy of the Universe will assume the form of equally diffused heat in which condition it will be useless.

The question arises, is there any phenomenon connected with matter of a similar kind? The answer must be in the affirmative if we consider those elements or some of them at all events, which are concerned with life. They undoubtedly exist in more and in less available forms so far as vital processes are concerned and there are causes in Nature which tend to "degrade" the former class into the latter.

Of the twelve elements which occur in the tissues of animals and plants four are of special importance, namely, - Carbon, Hydrogen, Oxygen, and

Nitrogen. Broadly speaking it is the function of a plant to decompose simple compounds of these elements such as carbonic acid, ammonia, nitric acid and water (-which it finds in nature, partly in the air and partly in the soil) and to build up from these, complex compounds such as starches, sugars and the so called albuminoids - a portion of the oxygen being returned to the air in the free state.

Animals have no such power but utilize the products of plant life for their nourishment, and in doing so they reverse the operations of the plant, breaking down part at least of the complex substances and converting them into carbonic acid, water and nitrogenous substances which easily yield ammonia:- these excreta returning to the air or the soil. Thus there is a perpetual "circulation" of these four elements in organic nature: the same particles serving for the vital processes of successive generations of living beings of both kingdoms. By this reciprocal action of plants and animals the balance of carbonic acid and oxygen is maintained in the atmosphere, as we have seen.

But will the balance always remain? are there not other causes at work tending to disturb it ?

One cause at least is not far to seek, for coal has undoubtedly been formed from plants, and our coal deposits therefore represent so much available carbon withdrawn from circulation. But against this we have the utilization of coal in our fires and furnaces which is gradually restoring it to the air as carbonic acid.

There is however, another and much more potent agency at work tending slowly but surely to convert the carbonic acid of the air into a form in which (unlike coal) it can never again become available for the vital processes of the organic kingdom.

This cause is to be traced to the geological changes which are occurring and which have occurred as the earth has cooled down.

Rocks are composed of two sets of constituents namely, acids and bases . Of the former the most important are silicic acid (silica) and carbonic acids, while of the latter the chief are, lime, magnesia, oxides of iron and the alkalies. If we heat

silica with the carbonate of one of these bases, carbonic acid is driven off and a silicate results; while if we act upon a silicate at ordinary temperatures with carbonic acid and water, it is decomposed, silica being liberated while carbonic acid is fixed.

It is probable that the earth was once in a glowing condition, and then the whole of the carbonic acid very possibly existed in a free state in the atmosphere. But with the progress of ages the conditions became altered and carbonic acid began to get the mastery as the cooling process went on, with the result that successive geological strata became richer in carbonates and the atmosphere poorer in carbonic acid. It has been stated that in this way "half the calcareous strata which compose a very large part of the crust of the earth, consists of carbonic acid derived from the atmosphere, and which has been withdrawn for ever from the cycle of life,"

Oxygen is probably undergoing a similar though probably a slower absorption into the crust of the earth - chiefly owing to its combination with the compounds of iron; and hydrogen also may be

disappearing owing to the fixation of water by various minerals. But with nitrogen the case is different though leading eventually to the same final result. With it we have to fear its liberation in the free state and not its absorption. This element is characterised by its great inertness: for which reason it chiefly occurs in the uncombined state and its presence even when combined, is restricted apparently to the upper layers of the earth's surface. The only natural causes at work leading to its absorption from the air in the form of compounds available for the nutrition of plants— are atmospheric electricity, by which nitric acid is produced from air and moisture, and possibly the evaporation of water which may give origin to nitrite of ammonium and has been asserted to do so by Berthelot. But if natural causes are at work in its fixation in the cycle of life, the operations of man are tending in the opposite direction, all processes of combustion in the ordinary sense, causing it to be liberated from its compounds and returned to the air in the uncombined condition.

Appendix F.

Atmospheric Dust and Micro-Organisms

That atmospheric dust contains in addition to pulverized minerals and the debris of plants and animals, the spores of living organisms, and that the latter play a most important role in nature, is now a well ascertained fact and it will not be out of place to give a brief sketch of this most interesting subject which indeed forms one of the great triumphs of modern science.

The study of aerial microbes originated in the celebrated controversy respecting spontaneous generation which culminated in the beautiful and classic researches of Pasteur.

The idea that life can originate from lifeless matter is a very old one and the ancients were deeply imbued with it. It is discussed again and again in their writings while in the Bible we find passages which evidently refer to it.

It is not hard to understand how in primitive

times

insects appeared to be generated spontaneously from corrupting matter, but on the other hand it is very difficult to imagine how the notion could have originated that the higher animals could be produced artificially. That such a belief prevailed is certain, for we find Van Helmont, a chemist of the 16th century, giving directions for manufacturing mice, and he even went so far as to maintain that fish are produced out of water.

The first to combat the doctrine of spontaneous generation was the Italian, Redi, who, by a very simple experiment, proved that flies are not produced spontaneously from putrefying meat. He merely enclosed fresh meat in a gauze cage, and observed that although the meat putrefied no maggots nor flies were developed <u>in</u> it. He watched the flies hovering over the enclosed meat, and by a mistaken instinct depositing their eggs on the gauze cage, and eventually he saw these eggs turn into maggots. He thus proved, by an experiment which we may agree with Huxley in calling childishly simple, that insects <u>are</u> produced from their parents and not formed

spontaneously as a product of corruption. Redi's experiments were sufficiently conclusive with regard to the mode of genesis of the higher animals, but after the construction of the microscope had been improved, when, in fact, the compound microscope came into use, the question of spontaneous generation was again brought prominently forward. For the microscope revealed countless organisms in ordinary water, and especially in infusions of animal and vegetable substances, such as meat broth and an infusion of hay. These organisms, or "infusoria", as they were called, are characterised by their extreme minuteness; hence the question of their origin presented considerable difficulties. If we examine an organic infusion recently prepared no sign of a living organism is visible, but in a few hours the liquid teems with myriads of minute beings. Whence have they come ? Are they produced spontaneously from the animal or vegetable substances present in the infusion ? Or are they the descendants of pre-existing beings which have gained access to the infusion in some way; are they formed from eggs or spores present in the water or in the substances

from which the infusions have been made ? The English observer Needham was the first to attack this problem experimentally about 1745. He argued that as heat destroys both the seeds of plants and the eggs of animals, a boiled infusion ought not to develope any living organisms. He tried the experiment i.e., he heated the infusions in hermetically closed vessels, and found that subsequently organisms did develope; hence he came to the conclusion that they were spontaneously produced. After these experiments the Italian physician Spallanzani took up Needham's work, and by heating the hermetically sealed infusions for a longer period, arrived at the opposite result - no infusoria appearing after the prolonged heating. Needham, however, was prepared with an argument to explain this result, his contention being that under the conditions of Spallanzani's experiment the germinating power of the infusion had been destroyed, and further that the air contained in the closed vessel had been vitiated by the heat. The latter part of this criticism acquired some force when it was discovered that the gases contained

in vessels of preserved provisions contained no oxygen, and oxygen is, as we know, essential to life. Swann, however, showed conclusively that if an infusion previously boiled is placed in communication with air that has been heated red hot, no putrefaction occurs. Ure and Helmholz multiplied Swann's experiments with the same result, and Schulz found that instead of calcining the air it is sufficient before admitting it to the boiled infusions to allow it to pass through energetic chemical substances, such as oil of vitriol, &c. These experiments were really sufficient to decide the question against the doctrine of spontaneous generation, but its supporters were hard to defeat, and clung tenaciously to their belief. Their objection at this stage of the controversy was ingenious, if nothing else. By calcining the air, or by passing it through energetic chemical substances, you destroy some principle in it which is essential for the production of infusoria, they said. It is all very well to say that you merely destroy the seeds or germs, but you offer no proof of such a thing.

This criticism had to be met, and it was met most ingeniously by Schroeder and Dusch, the method which they employed being simply a refinement of Redi's experiment with the gauze cage round the meat.

Instead of the gauze cage they used cotton wool, merely allowing the air to filter through it before coming in contact with the well boiled infusion. Under these conditions they found that the latter remained perfectly sweet and fresh, showing no trace of organisms when examined under the microscope, nor the slightest symptom of putrefaction, except in the case of milk and eggs. It is, they argued, difficult to imagine that the wool can have removed anything from the air except solid particles, and these must be the germs of the infusoria.

It only remained to demonstrate, first, that these germs are actually present in air, and secondly, that they are retained by the cotton wool. Independently Tyndall and Pasteur devoted themselves to this branch of the subject, and arrived at positive results by two totally different methods.

In Pasteur's beautiful researches, which are remarkable for their simplicity, elegance, and aptness, ordinary air was filtered through gun cotton wool, and as thus purified was found to have lost its power of inducing putrefaction in organic liquids. Pasteur then submitted the minute residue which was left on dissolving the gun cotton, to microscopic examination. In it he had no difficulty in recognising the spores of minute organisms; and to complete the proof that these spores are actually the seeds of putrefactive organisms, he brought them into a previously boiled infusion, and found that in the course of a few hours the liquid was in active putrefaction.

Tyndall's experiments were based upon totally different considerations. Every one knows that when a ray of sunlight enters a dark room its path is clearly visible. The ray looks like a faint luminous cloud, and if the cloud is examined narrowly myriads of particles are seen to be floating in it. Now, Tyndall found that by allowing air to remain perfectly quiet and undisturbed for a day or

two these particles by their natural gravity subside, and a ray of light when now passed through the air no longer shows any visible track.He proved by a simple experiment that air before subsidence causes organic infusions to putrefy, whereas after subsidence the infusion may be exposed for any length of time to it without undergoing the slightest putrefactive change.

It was thus definitely proved that putrefaction is caused by minute organisms, the spores of which are present in air, and that it is not due to any spontaneous change occurring in the putrescible matter, nor to any specific action of the air as such. The minute organisms are produced from spores or eggs, and the doctrine of spontaneous generation was in this way finally refuted.

At first sight putrefaction appears to be a totally useless process, involving as it does the destruction of useful material which has been formed by the very elaborate and complex operations of living plants and animals - operations requiring much time and it might be even said labour also,but

in reality it is a very beautiful device of nature's for disposing of dead organic matter, and for converting it into substances which can again serve for the nourishment of plants and animals. But for it this earth would be a vast charnel-house; we should be surrounded by the emblems of death, and not only so, but as the supply of substances suitable for the nourishment of plants and animals is limited, each race would gradually diminish the stock, which would eventually become exhausted and the world no longer habitable. As it is, however, no sooner does a plant or animal die or give up its excretions, than the remains are fastened upon an army of scavengers, who gradually reduce them to simple compounds which are either dissipated in the air, washed away by water, or go to form earth.

This army of scavengers consists of micro-organisms, and although much has been done towards their study, much still remains to be done before we shall be able to say definitely what their exact functions are. Thus we do not know at present how many species there may be engaged in the work, nor do we

know with any exactness how each species acts. It would appear, however, that putrefaction is by no means a simple process, and that before a complex substance like albumen or white of egg can be resolved into simple bodies like ammonia, water, and carbonic acid, it has to be attacked by successive gangs of these minute labourers, each gang dying off after completing its share of the work and leaving things in order for the operations of the next.

Most of the organisms in question are very minute and belong to the vegetable kingdom. Roughly speaking they may be divided into three groups viz:- Moulds, Yeasts, and Bacteria. The latter are specially interesting and have been called collectively "Schizomycetes" - literally "Splitting" fungi (german "Spaltpilze") from their peculiar mode of reproduction, which merely consists in the division of one individual into two, a process which occurs with great rapidity. They are the most minute of all micro-organisms, and measure only a few thousandths of an inch in length.

They vary in shape, some being nearly round

(Micrococci) others presenting a rod like form (Bacilli), while others again are spiral (Spirilla).

Some are mobile, their movements (which are often very rapid) being caused by whip like appendages (Flagella).

Apart altogether from the process of multiplication by fission some of the Schizomycetes have another mode of reproduction viz:- by means of permanent spores. These spores are remarkable for their powers of resistance to agencies which would be fatal to the mature organism. Thus the spores of the hay bacillus may be boiled in water for a considerable time without losing their vitality.

Our present knowledge of micro-organisms depends largely upon the methods which have been devised for separating the various species from each other and obtaining them as pure "cultures". At first the problem presented considerable difficulty, for if we consider for one moment that the spores of countless species swarm in the air, and are present in ordinary water and in animal and vegetable matters, we can easily see that the isolation and

cultivation of one particular species is a difficult task: for how exclude the others ? An agriculturist would be puzzled to know how to raise a crop of corn without any weeds whatever if he were not permitted te remove the weeds as they appeared. The bacteriologist is called upon to perform a similar process, but the weeding operation is denied him. How has this difficulty been overcome?

We are indebted mainly to Koch for having solved this problem, and for having devised a beautiful and ingenious method which has marked quite an epoch in bacteriological science.

Koch takes a nourishing medium containing gelatine, which is sterilized by heat, and when cold solidifies to a jelly. He then introduces into the gently-warmed medium a droplet of liquid containing the organisms to be cultivated (and possibly other organisms also): and then pours the mixture upon a glass plate which has been previously heated to a high temperature to destroy any organisms present in the dust on its surface. The plate is finally put beneath a bell-shaped jar on blotting

paper previously soaked in corrosive sublimate solution. By this means the jelly is kept moist, and at the same time protected from dust.

Consider the effect of this operation. The organisms or their spores present in the liquid with which the gelatine was "inoculated" are presumably equally distributed, and if only a few are present (which can be ensured by diluting the liquid used for inoculating) each individual is separated from another by a considerable space, and as the gelatine solidifies it is fixed in a permanent position.

In course of time (only a few hours under favourable conditions) each organism reproduces itself, eventually forming a colony, and this colony liquefies the gelatine at a particular spot or causes an opacity. Hence we may be certain that liquid taken from this spot contains only one species of organism, and with this we can inoculate a sterile liquid and so obtain a pure culture. This beautiful method of Koch's has been employed by him for isolating and investigating many of the organisms

of disease, and can be used for measuring the number of organisms in air, water, and other fluids.

That certain micro-organisms are the active causes of many of the most serious diseases which attack men and the lower animals is now an established fact in Science, and as the subject is of great interest and importance - more especially as it appears to be almost certain that in many cases air is the vehicle for the transmission of these diseases, a few remarks may not be out of place here.

The first observation in the direction of establishing a connection between micro-organisms and disease was made by two French doctors, Messrs Rayer and Davaine, to the effect that the blood of animals dead of splenic fever teems with minute rod-like bodies resembling the bacilli found in hay infusion.

Rayer and Davaine made this observation in 1851, but at the time they do not appear to have laid any great stress on it. It was subsequently confirmed in Germany in 1857, by Pollender and Brauell. At that time, however, the entire subject of micro-organisms was in its infancy, their

nature and effects were not understood, and no doubt it would have appeared ludicrous to assums for a moment that a minute organism, quite invisible to the naked eye, could attack and slay in a few hours a huge animal like an ox. But after Pasteur's memorable researches in 1861, on the ferment of sour milk, it was clearly shown that in spite of their minuteness , micro-organisms can produce very marked and extensive effects, even in a large quantity of matter, and Pasteur's work impressed Davaine so strongly with the potency of micro-organisms, that he once more returned to his observations of 1851, and became impressed with the belief that the bacilli observed in the blood of animals dead of splenic fever were no mere accidental accompaniments of the disease, but its actual cause.

But a much more complete chain of evidence was necessary before it could be considered as definitely established that Anthrax was indeed caused by micro-organisms, and without tracing the history of the subject further it will be sufficient to indicate how the complete proof was eventually furnished.

1st. We always observe in the blood and tissues of animals suffering from the disease, rod-like organisms or bacilli.

2nd It is possible to inoculate (with every precaution) an artificial nourishing medium - say nutrient gelatine - with this blood, and we find characteristic colonies from which we can obtain a pure culture of the bacillus, with which we can inoculate a sterile nourishing fluid, like broth.

3rd On injecting this broth into a healthy animal - a mouse, a guinea pig, a sheep, or an ox, we find after a short interval all the characteristics of splenic fever. The animal usually dies, and in its blood are found countless bacilli of the kind from which we originally started.

The argument appears complete, and I believe that Koch was the first to maintain that no organism could be considered as the cause of a disease, unless all the above conditions are fulfilled.

Koch has formulated the above conditions, thus-

(1) It is absolutely necessary that the micro-organisms in question be present in the blood or

diseased tissues of man or animals suffering or dead from the disease. (In this respect great differences exist, for in some infectious diseases the micro-organisms, although absent in the blood are present in the diseased tissues, whilst in others they are present in large numbers in the blood only, or in the lymphatics only - Klein.)

(2) It is necessary to take these organisms from their nidus - from the blood or tissues as the case may be - to cultivate them artificially, i.e. outside the animal body, but by such methods as exclude the accidental introduction into these media of other micro-organisms; to go on cultivating them from one cultivation to another, for several successive generations, in order to obtain them free from every kind of matter derived from the animal body from which they have been taken in the first instance.

(3) After having thus cultivated the micro-organisms, it is necessary to re-introduce them into the body of a healthy animal susceptible to the disease, and in this way to show that the animal becomes

affected with the same disease as the one from which the organisms were originally derived.

(4) It is necessary that in this so affected new animal the same micro-organisms should again be found. "A particular organism may be the cause of a particular disease, but, that really and unmistakably it is so can only be inferred with certainty when every one of the above conditions are fulfilled." (Klein.)

* * * * * * * * * * *

Many observations have been made by Pasteur, Miquel, Freudenreich, Percy Frankland and others on the number, nature and distribution of the organisms present in air. Hesse's method for measuring their number consists in drawing a measured volume of the air to be examined through a wide glass tube coated internally with a nutrient jelly previously sterilized by heat. All the organisms and their spores are deposited on the gelatine, as the air passes through the tube; if the current is not too strong: then after a day or two each produces a colony which is apparent as a speck, and the number of these

colonies can readily be counted.

Although the number of observations made as yet is not sufficient to form any very wide generalizations, the following points seem to have been established.

On land at ordinary levels the number of organisms varies enormously - from only one or two in a litre of air to several hundreds. The number depends upon a variety of circumstances, but chiefly to those causes which give rise to atmospheric dust, such as movements of air produced by winds, and the motions of men and animals. No doubt also the nature of the dust is an important factor: that arising from dried animal or vegetable refuse probably containing far more organisms than dust derived from pulverized minerals &c.

Locality as might be expected has a very decided influence. Thus Frankland found as the mean of a series of observations on the roof of the South Kensington Museum between January and June 1886, 3·6 organisms per litre of air. Near Reigate and the vicinity of Norwich 1·4. In Kensington Gardens,

Hyde Park, and on Primrose Hill 2·4.

In a given locality the greater the elevation the less is the number of micro-organisms. Thus at St. Paul's Cathedral, Frankland found at the base 5·6 per litre, 2·9 in the stone gallery, and 1·1 in the golden gallery: at Norwich Cathedral 1·8 at the base 0·9 at a height of 180 feet and 0·7 at 300 feet elevation. The air on high mountains is singularly free from micro-organisms, and very possibly the curative powers of some of the Swiss health resorts, such as Davos Platz and the Engadine are to be traced, in part at all events, to this cause.

The seasons also are not without their influence on the number of aerial micro-organisms. Experiments made at the Montsouris observatory, showed that there were far less during winter than in spring and summer: and Frankland in an elaborate series of observations has proved the same thing, (see plate 19): according to him the number is proportional to the temperature. From the Montsouris

observations the number seems also to be connected with rain, for while in warm months it was 28 per litre, after heavy rain it rose to 95 and even 120.

As might be expected ocean air is very free from organisms - their number decreasing with distance from land. When this distance reaches from 70 - 120 sea miles, the air is entirely free from them.

Finally, comparisons of the total number of dust particles in the air with those which are either micro-organisms or their spores have not as yet been made, (so far as I am aware,) although the subject deserves attention. But from a comparison of the few observations made by Aitken on the former, and of the latter by Frankland, the highest ratio of living (or potentially living), to dead or inorganic particles would appear to be small: probably not more than one to ten million.

PRIESTLEY'S APPARATUS

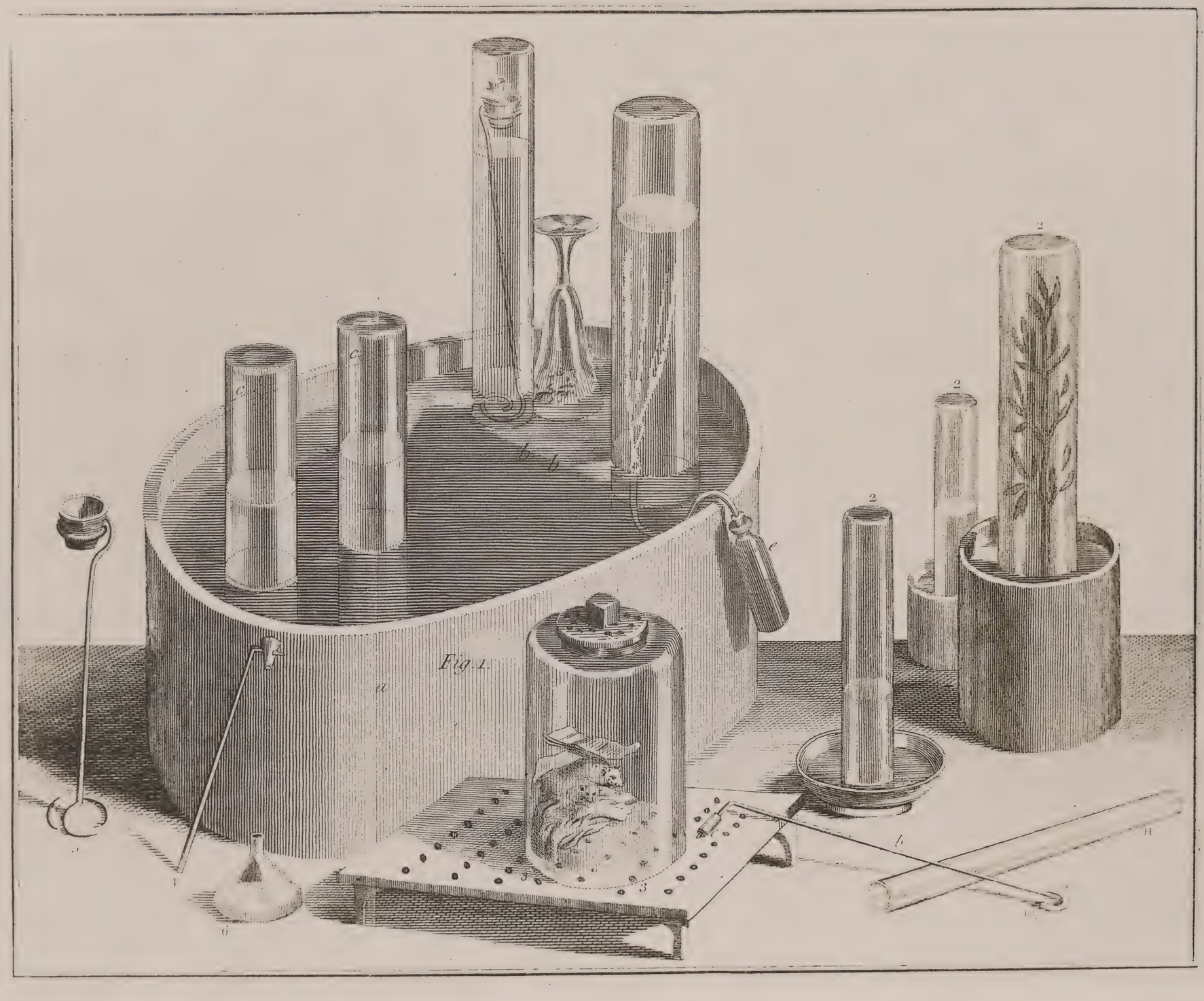
Priestley was a Unitarian Minister, but was devoted to scientific pursuits. As one of the great pioneers in the investigation of gases, his researches and their far reaching results were simply marvellous.

In the two plates shown - which I have photographed from his book - a very graphic picture is given of the homely appliances he made use of.

In Plate 1, the pneumatic trough (which he originated) is shown. It is merely a tub of water with a shelf, and gases are shown in process of collection in vessels filled originally with water, and then inverted on the shelf. A gas, which is being generated in an ordinary bottle, is seen bubbling through the water and displacing the latter from one of these jars. An apparatus is also displayed

for obtaining oxygen, probably by heating oxide of mercury in a crucible supported on a wire - by means of a burning glass (not shown). In the fore ground, a number of mice appear in a glass vessel, and one of them is represented as breathing some gas contained in a goblet over the pneumatic trough. On the right various vessels are seen standing over water and containing gases. While on the extreme right, a vegetable is plunged in water, and is disengaging oxygen,- for Priestley discovered this fact.

Plate I



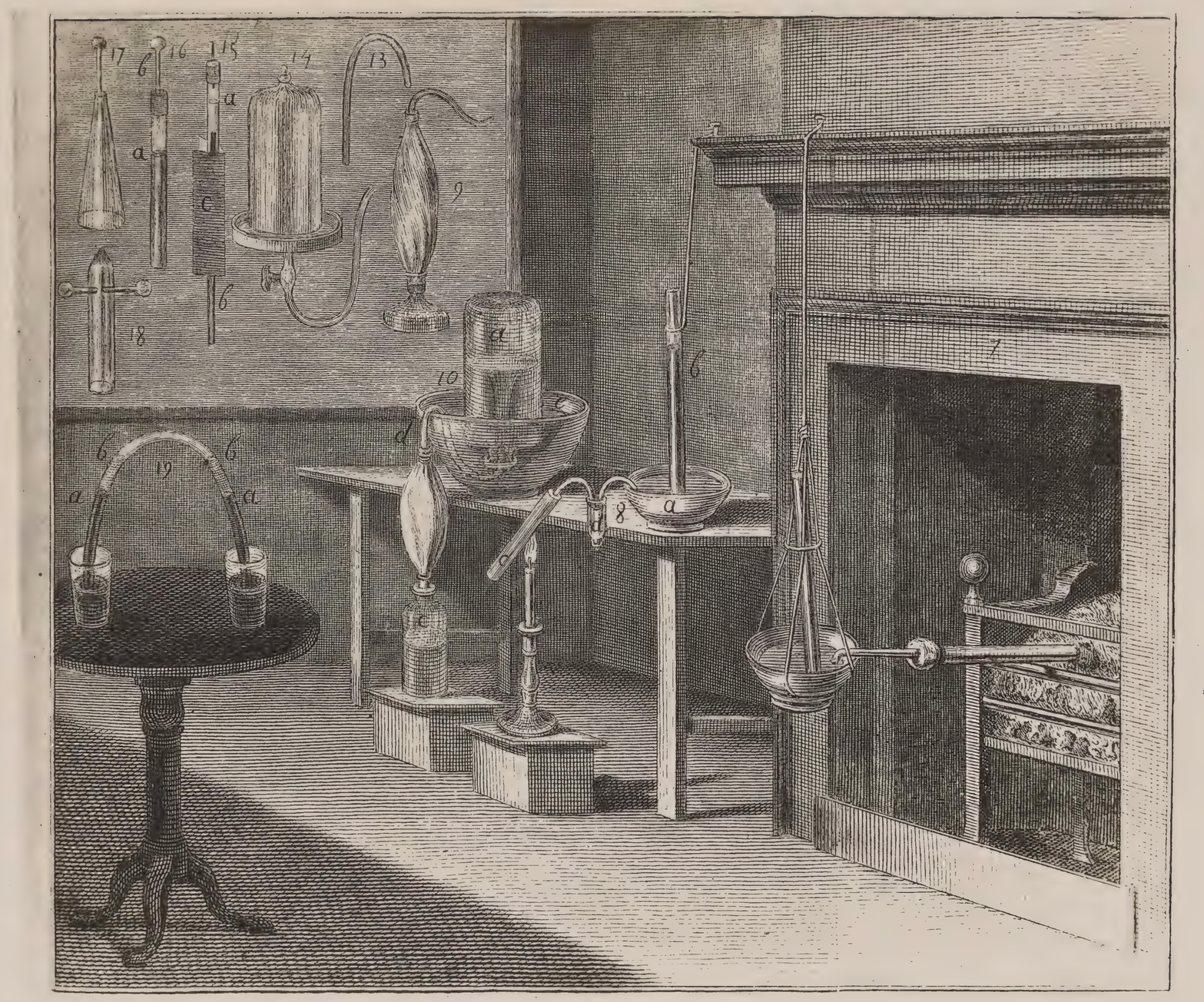
Priestleys Apparatus

PRIESTLEY'S APPARATUS

In Plate 2, various pieces of apparatus are represented in operation. For instance, a gas generated in a tube heated in the fire-place, and collected in an extemporized pneumatic trough, consisting of a basin hung to the mantel-piece. In the centre, a gas produced by the heat of a candle on some substance contained in a tube, and another gas entering a bladder, and thence passing into a bottle, standing over a pneumatic trough, are shown.

In the back ground, diagrams are probably represented, and on the left, a table is displayed, on which two tumblers are placed, containing a liquid which is absorbing a gas contained in the bent tube which connects them.

Plate 2



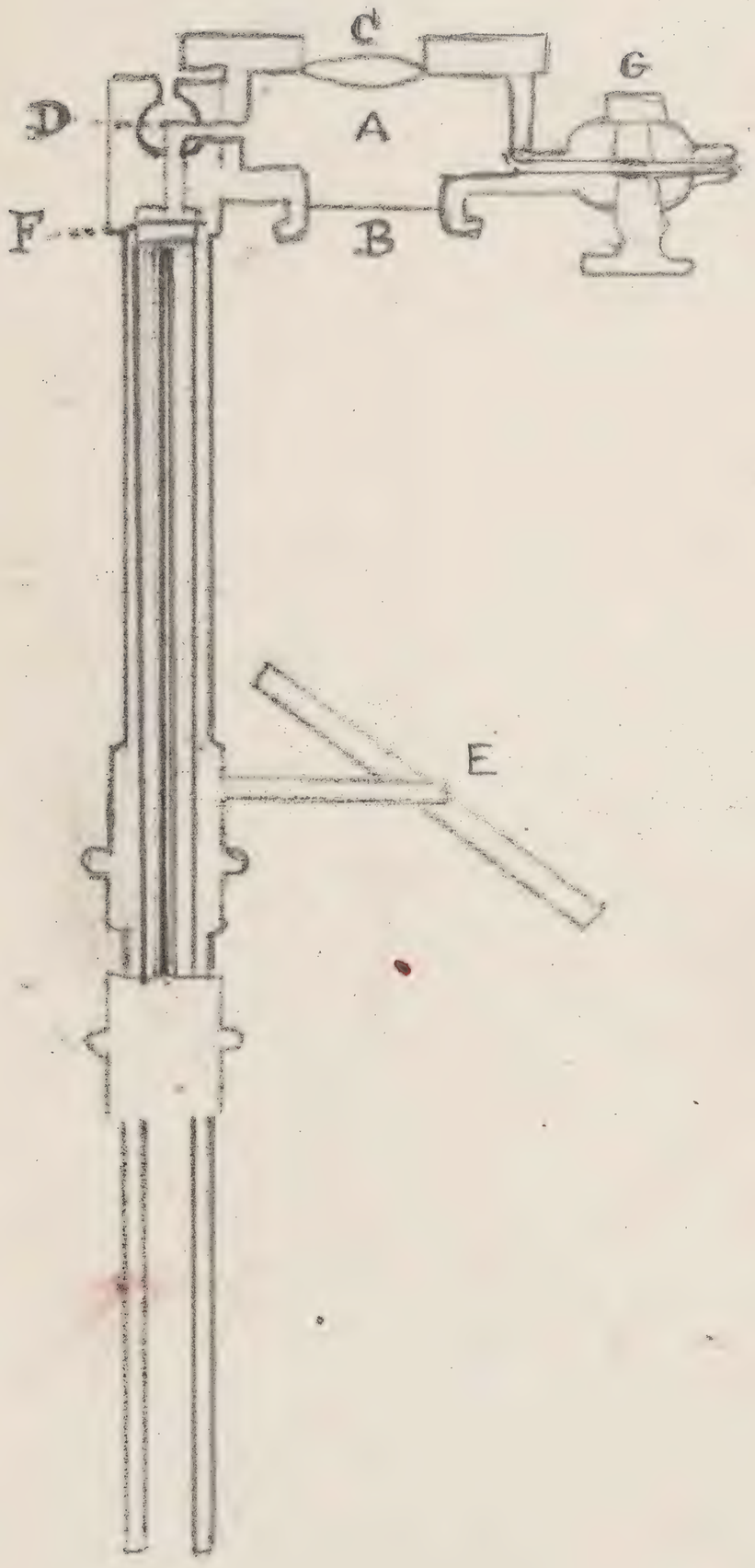
Priestley's Apparatus

Plate 3.

Daniel's Dew Point Hygrometer.

Plate IV

AITKENS DUST COUNTER



The marginal sketch shows a section of the apparatus. It consists of a chamber A, kept moist by wet blotting paper, into which the air to be examined is admitted through the taps D, after a vacuum has been produced by drawing down the piston F, of the pump.

The minute rain drops which form on the dust particles, are deposited on the glass plate B, ruled into squares to facilitate their being counted, and illuminated by the mirror E. The small stopcock G, is used for examining, very pure air. To use the apparatus, the air in the receiver A is first purified by opening the

Plate 4

Aitken's Dust Counter.

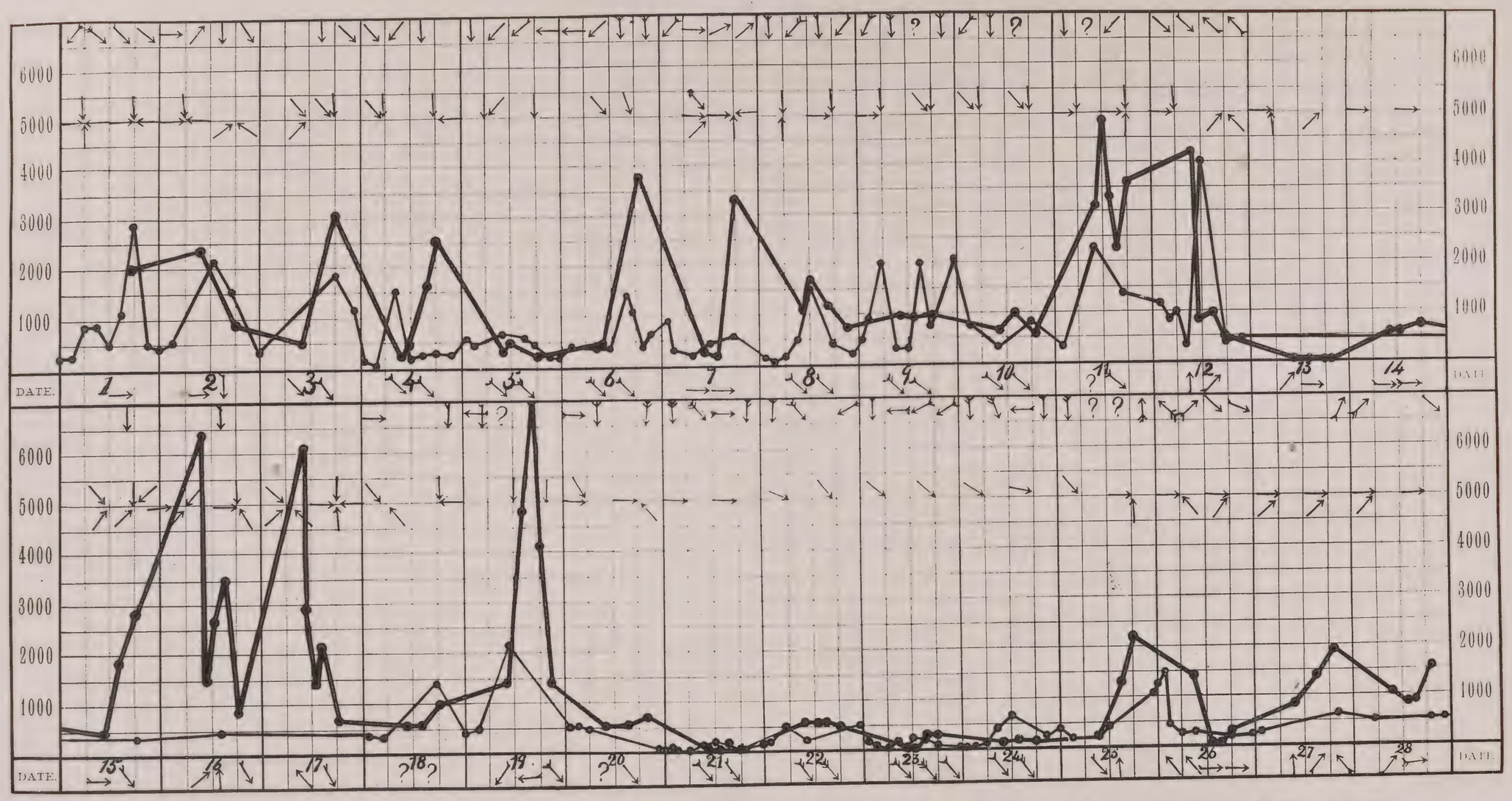
stopcock G and pushing the portion F to the top of its stroke - the large stopcock being in the position shown. The eye is now applied to the lens and the piston drawn down. If the air is very impure nothing will be seen when this is down. But if the piston is pushed up and again drawn down a shower of fine drops is seen to fall: by repeating the operation two or three times the drops grow fewer and larger and finally cease falling altogether. The air in the receiver is now dust free and a test may be made.

For this purpose the large stopcock D is turned a quarter to the left which allows any air which may have leaked in to escape: the stopcock is then returned to its original position. The portion is next drawn down to one of the marks on the scale, say to the first mark which takes out 1/50 of its contents. The stopcock is now turned a quarter to the left which allows the measured quantity of air to enter the receiver, while the pump is pushed up to get rid of air in the piston. The instrument is next moved to and fro which causes a stirrer (not

shown), inside the receiver to fall and to mix the impure 1/50 with the pure moist air. Finally the eye is applied to the lens and attention is fixed on one of the squares or on four and the precipitated drops are counted. I am indebted to the kindness of Mr Hume (1 Lothian St. Edinburgh) the maker of the instrument for the above description, and also for the loan of the instrument.

Plate 5

DIAGRAM SHOWING THE NUMBER OF DUST PARTICLES IN THE ATMOSPHERE AT BEN NEVIS AND KINGAIRLOCH DURING JULY 1890.



The Thin Line shows the number of Particles at Ben Nevis.
The Thick Line shows the number of Particles at Kingairloch.

The Upper Arrows show the direction and force of the Wind on Ben Nevis.
The Lower „ „ „ „ at Kingairloch.
The Intermediate „ „ of the Winds over the British Isl

Aitken's Dust Curves.

ORGANISMS DEPOSITED FROM AIR, GROWING ON COOKED POTATOES.

The photograph is from nature, and shows four halves of ordinary potatoes which have been cooked, and then cut through with a heated knife, afterwards exposed for about 12 hours in ordinary air, and then placed in a moist and dust free atmosphere for about a week. The colonies produced by each organism, falling from the air are clearly seen, the large majority being moulds. The yeasts and schizomycetes form the minority, and show themselves as well defined (and sometimes coloured) round spots - much smaller at this stage of their developement than the corresponding mould colonies.

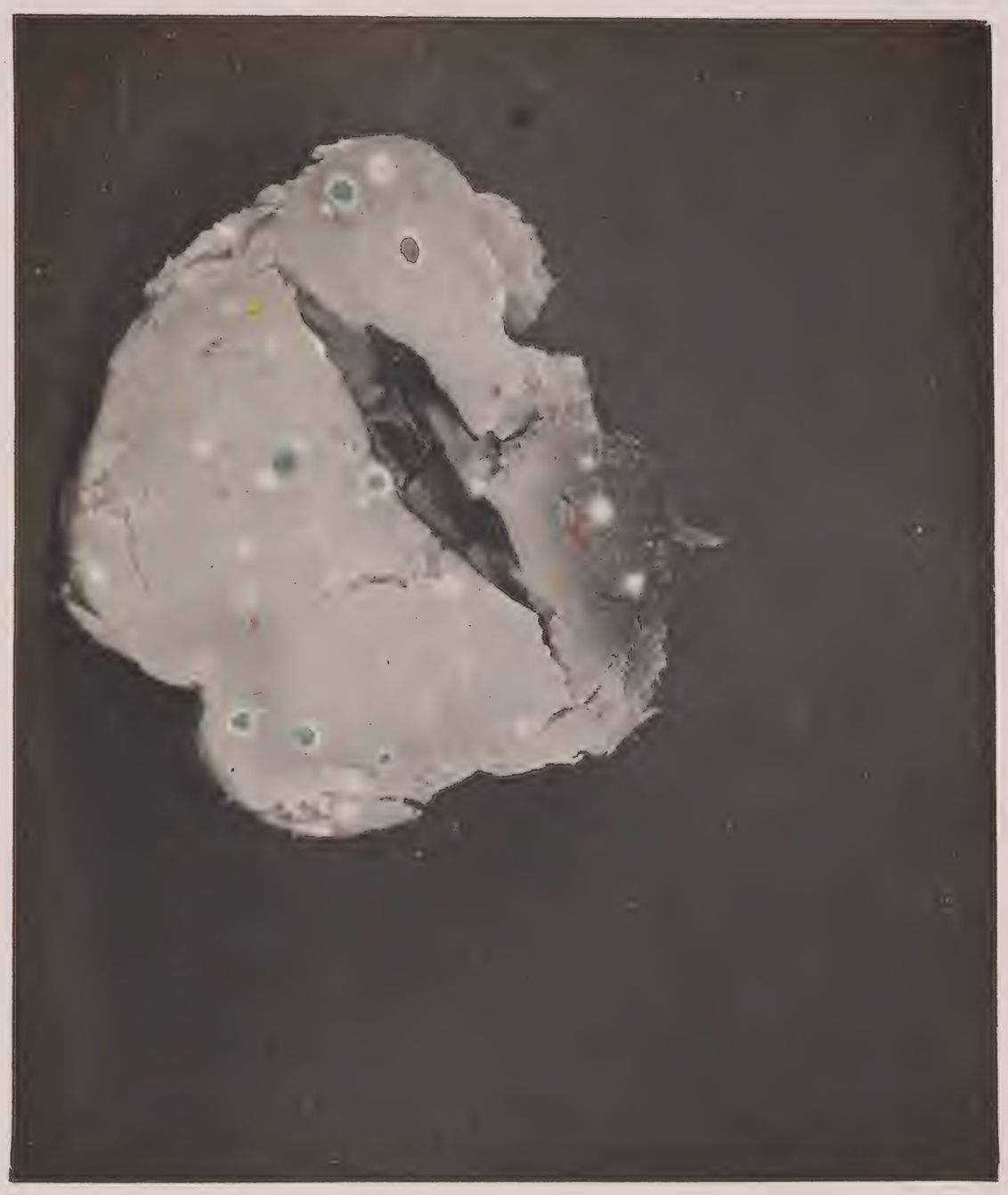
Plate 6

Organisms Deposited from Air.
Growing on Cooked Potatoes.

ORGANISMS DEPOSITED FROM AIR, GROWING ON COOKED POTATOES.

This plate, obtained in the same way as the last, has been coloured, and as far as possible, represents the original.

Plate 7



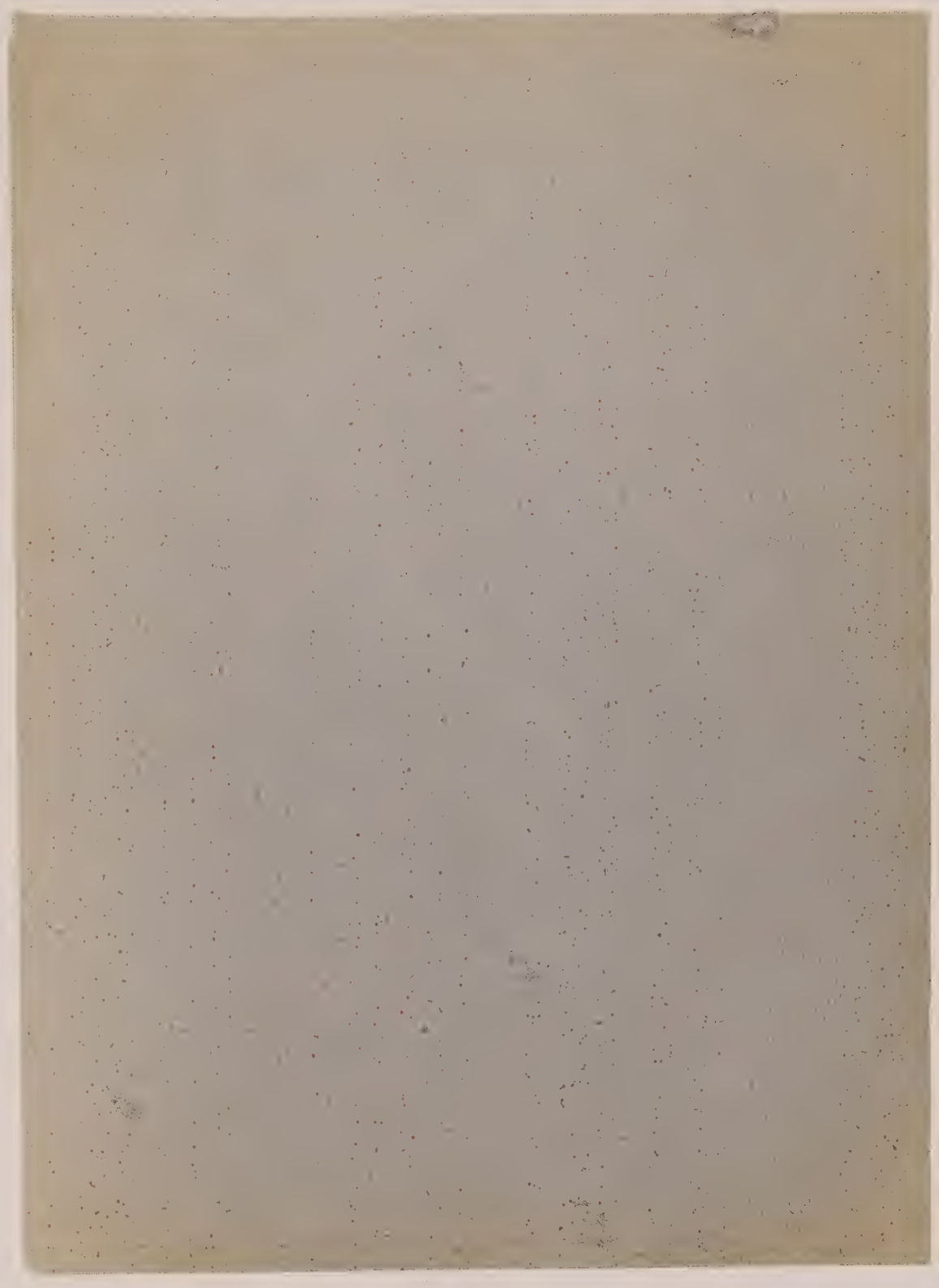
Organisms Deposited from Air;
Growing on Cooked Potatoes.

CULTURE OF MICRO-ORGANISMS ON GELATINE PLATES.

Plate 8, is an actual photograph obtained from an organism of the Yeast tribe, prevalent in air, and characterized by the pink colour of its colonies.

A colony of the organism which had been deposited from air, and was growing on the potato shown on Plate 7, was removed on the point of a previously heated platinum wire into a test tube containing nutrient gelatine mixture (previously sterilized by heat), and the mixture well agitated. The major portion was then poured onto a glass plate (previously sterilized by heat), and the latter placed in a moist chamber for about a week. The colonies thus obtained are minute and closely packed.

Plate 8



Culture of Micro-Organisms on Gelatine Plates

CULTURE OF MICRO-ORGANISMS ON GELATINE PLATES.

Plate 9, shows colonies of the same organism, obtained precisely in the same way as those on Plate 8, and after the same period of time. They resulted from introducing a drop or two of the gelatine remaining in the test tube used for the former cultivation, into a second test tube of the sterile gelatine mixture. They were thus very largely diluted. As a consequence they had more food and developed more rapidly. The larger colonies are growing on the surface, showing that for their rapid developement they require air, while the smaller ones are deeply embedded in the gelatine.

Plate 9

Culture of Micro-Organisms on Gelatine Plates

CULTURE OF MICRO-ORGAMISMS ON GELATINE PLATES.

Plate 10, was obtained at the same time, and under the same conditions as the former plate, the only difference being, that a drop of the gelatine mixture remaining in the test tube from the second dilution, was introduced into a third tube of the nutrient mixture, and thus still further diluted. As a consequence there are very few colonies, and these are widely separated and well developed.

Plate 10.

Culture of Micro-Organisms on Gelatine Plates.

CULTURE OF A SINGLE ORGANISM IN A TUBE OF NUTRIENT GELATINE.

The plate shows a test tube originally containing sterile gelatine mixture, but subsequently "inoculated" by plunging a (previously heated) wire into it, which had been allowed to touch a colony of pure organisms (cultivated on a gelatine plate). The growth of the organism is shown by the opacity formed in the needle track and expanding into a white layer on the surface.

Plate II

Culture of a Single Organism
In a tube of Nutrient Gelatine

BLUE MOULD (PENICILLIUM GLAUCUM)

Highly Magnified.

The plate shows the mould (which was inoculated with a wire from one of the potato colonies, on to a gelatine plate) - actually growing. The mycelium or stalk, is clearly seen, terminated by the sporangium or seed vessel. The spores (or seeds) are seen, arranged like strings of beads,- some having been separated by pressure applied to the covering glass.

Plate 12

Blue Mould. (Penicillium Glaucum)

A COMMON FORM OF MOULD. (MUCOR-MUCEDO)

Highly Magnified

The micro-photograph was taken from a prepared specimen.

Plate 13

A common form of Mould (Mucor Mucedo.)

Y E A S T.

(Highly Magnified)

This micro-photograph is the work of Mr Swan, of the Bushmills Distillery, (Co. Antrim, Ireland). It shows one of the many varieties of yeast in the living and growing condition.

Plate 14

Yeast (A variety of Saccharomyces)

MICRO-COCCI.

(Highly Magnified)

The photograph is taken from the actual organisms, very highly magnified.

Plate 15

Micro- Cocci.

B A C I L L I.

(Highly Magnified)

The photograph is taken from actual organisms, very highly magnified.

Plate 16

Bacilli.

S P I R I L L A.

(Highly Magnified)

The photograph is taken from the actual organisms very highly magnified.

Plate 17

Spirilla.

ORGANISMS OF DISEASE.

TUBERCULOSIS

(Highly Magnified)

The photograph is taken from the sputum of a person suffering from consumption or "tuberculosis", and is very highly magnified.

Plate 18

Organisms of Disease
Tuberculosis.

Plate 19

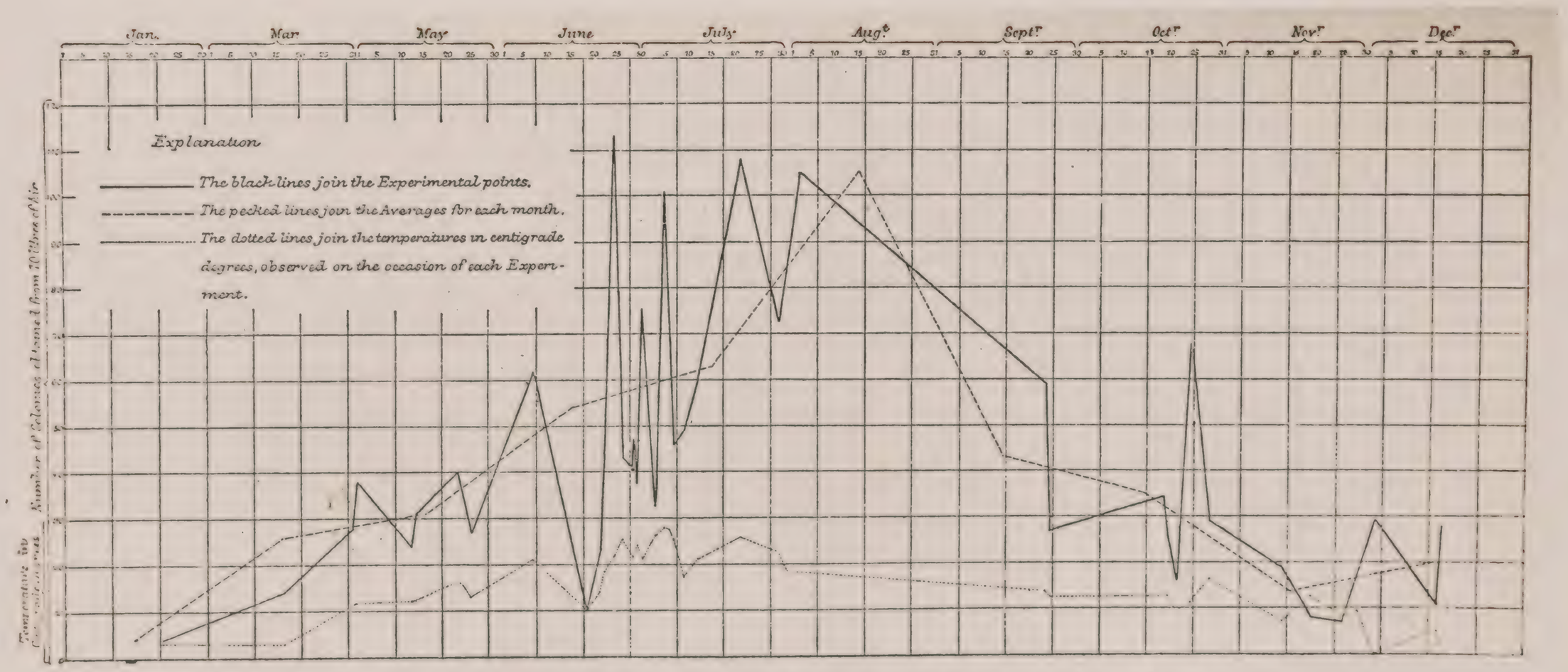


Fig. 12.—Curve showing the monthly variation in the number of aërial Micro-organisms during the year 1886. (*Percy Frankland.*)

Frankland's Micro-organism Curve